



केवल कार्यालयीन उपयोग हेतु
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भारत सरकार GOVERNMENT OF INDIA
रेल मंत्रालय MINISTRY OF RAILWAYS



HANDBOOK ON MAINTENANCE OF ELECTRICAL GENERAL SERVICES SUB-STATION

TARGET GROUP : GENERAL SERVICES MAINTENANCE STAFF

CAMTECH/ E/11-12/Sub-station/1.0

September, 2011



**Indian Railways
Centre for Advanced Maintenance Technology**

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*HANDBOOK
ON
MAINTENANCE OF ELECTRICAL
GENERAL SERVICES SUB-STATION*

QUALITY POLICY

"To develop safe, modern and cost effective Railway Technology complying with Statutory and Regulatory requirements, through excellence in Research, Designs and Standards and Continual improvements in Quality Management System to cater to growing demand of passenger and freight traffic on the railways".

FOREWORD

Uninterrupted electric power supply is essential for platforms, station building, service building and staff quarters. The maintenance practices followed, play a vital role in ensuring reliable power supply.

At present different Zonal Railways are having different maintenance practices of the electrical general service sub-station. Need has been felt for a hand book on maintenance aspects of Electrical General Services Sub-station. CAMTECH has made an effort in this direction by suggesting maintenance schedules for various sub-station equipment and maintenance tips to improve reliability. It also contains information on failures, their trouble shooting and an approach to investigation.

I hope this hand book will be useful to maintenance personnel and will assist them in keeping the sub-stations in excellent working condition with high reliability.

CAMTECH, Gwalior
Date: 21.09.2011

S. C. Singhal
Executive Director

PREFACE

The proper upkeep and maintenance of sub-station & its equipment are necessary to ensure reliability and availability of electrical power supply to the users. A well planned maintenance schedule of each & every equipment will ensure trouble free service and reduction in interruptions / failures.

This handbook on maintenance of Electrical General Services Sub-Station has been prepared by CAMTECH with the objective to disseminate knowledge among the working personnel and making aware of maintenance techniques to be adopted in field.

This handbook includes brief description of various sub-station equipment, their maintenance schedules, maintenance tips to improve reliability, causes and remedial measures of failure along with an approach to failure investigation.

It is clarified that this handbook does not supersede any existing provisions laid down by RDSO or Railway Board/Zonal Railways. This hand book is for guidance only and it is not a statutory document.

I am sincerely thankful to EEM Directorate of RDSO/ Lucknow and also all field personnel specially SC Division who helped us in preparing this handbook.

Technological up-gradation & learning is a continuous process. Please feel free to write to us for any addition/modification in this handbook.

CAMTECH, Gwalior
Date: 21.09.2011

Peeyoosh Gupta
Jt. Director Electrical

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ISSUE OF CORRECTION SLIPS

The correction slips to be issued in future for this handbook will be numbered as follows :

CAMTECH/E/11-12/Sub-Station/C.S. # XX date-----

Where “XX” is the serial number of the concerned correction slip (starting from 01 onwards).

CORRECTION SLIPS ISSUED

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Chapter 1

INTRODUCTION

Electrical General Services Sub-station is a distribution sub-station from which electric supply is distributed to the different users. In a substation there are numbers of incoming and outgoing circuits each having its isolator, circuit breaker, transformers etc. connected to bus-bar system. These equipment are mostly static type. Safety and protection of equipment as well as working personnel is also a considerable factor. Lightning arresters, earthing of equipment and fencing is done for this purpose. Maintenance of a sub-station is essential to ensure un-interrupted electric supply to the using points which involves vigilance, care and well-defined scheme of procedures. Such scheme indicates the authority and responsibility of persons at various levels. It consists of many of periodic schedule maintenance, regular inspections, testing and rectification of defects.

SINGLE LINE DIAGRAM OF 33 OR 11 kV/440 V SUBSTATION

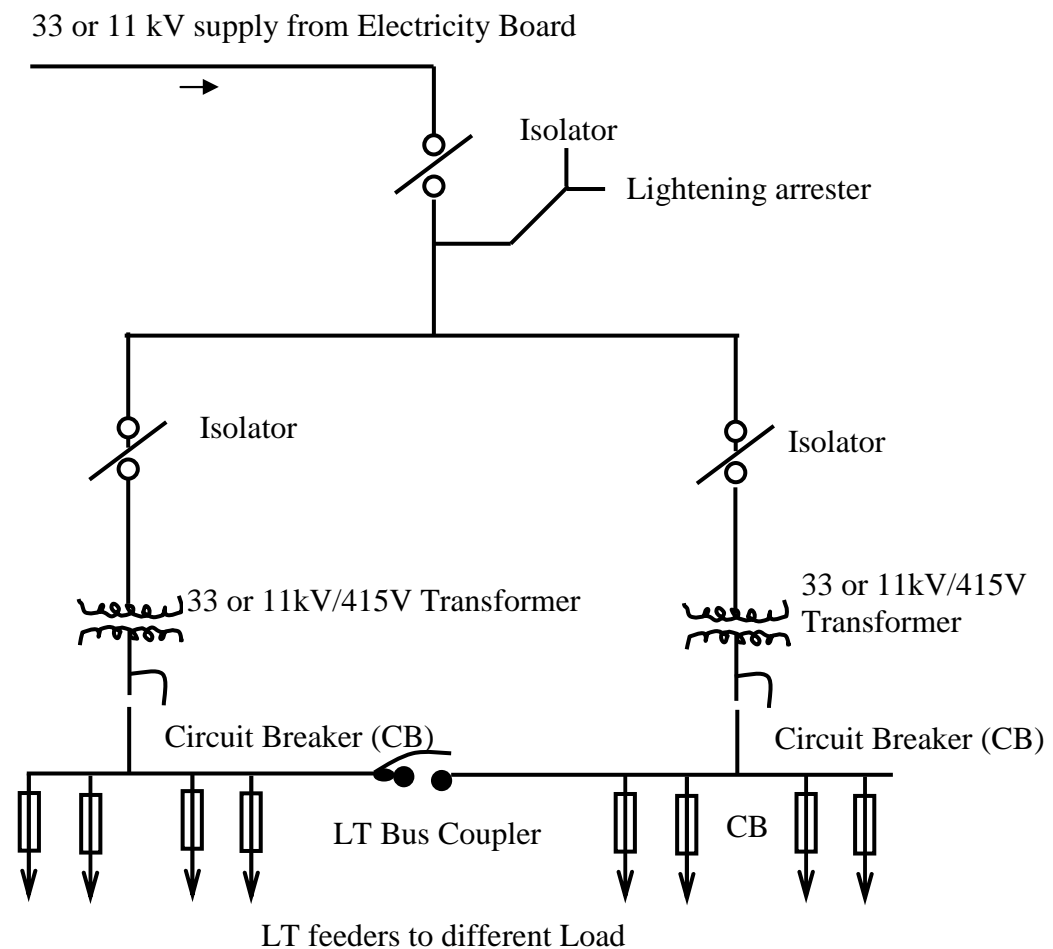


Figure 1.1 Single Line Diagram of 33/11 kV/440 V Sub-station

Upkeepment of records of each inspection is essential. If any replacement is carried out or adjustment of certain setting is done then these must be entered in a logbook. A rigid system of maintenance of each equipment will ensure long life, trouble free service and reduction in unnecessary interruptions. All work on major electrical installations must be carried out under permit to work system.

The “permit to work” is to be issued through permit card only by an authorized person. As the name suggests it authorizes the maintenance supervisor and his team to carry out work. Furthermore, this card will indicate unambiguously the points at which it is safe to work, the time interval when it is to be done, steps to be taken to ensure safety such as earthing, display of danger notices etc. at the nearest live point. It should have the signature of the authorized person. After the work is completed the permit card should be cancelled and it should be taken back. Danger notices should be put up or removed by the responsible supervisor who will take the charge of keys equipment, rooms, etc.

1.1 EQUIPMENT IN DISTRIBUTION SUB-STATION

The following equipment are installed in Electrical General Services Sub-station:

1. Distribution Transformer
2. Circuit breaker
3. Lightning Arrester
4. Air Break (AB) switches/ Isolator
5. Insulator
6. Bus-bar
7. Capacitor Bank
8. Earthing
9. Fencing
10. Distribution panel board

1.1.1 Distribution Transformer

The distribution transformer is a main and largest equipment of Electrical General Service Sub-station. It is basically a static electrical device which steps down the primary voltage of 33kV or 11 kV to secondary distribution voltage of 415-440 volts between phases and 215 volts between phase and neutral through delta-star windings by electromagnetic induction without change in frequency.

Transformer consists of the following parts and components.

- | | |
|---------------------|---------------------|
| • Primary winding | Secondary winding |
| • Transformer tank | Conservator |
| • Cooling tubes | Breather |
| • Buchholz Relay | Explosion vent |
| • Tap changer | Oil inlet valve |
| • Oil outlet valve | Oil level indicator |
| • L.T. terminals | H.T. terminals |
| • Temperature gauge | |

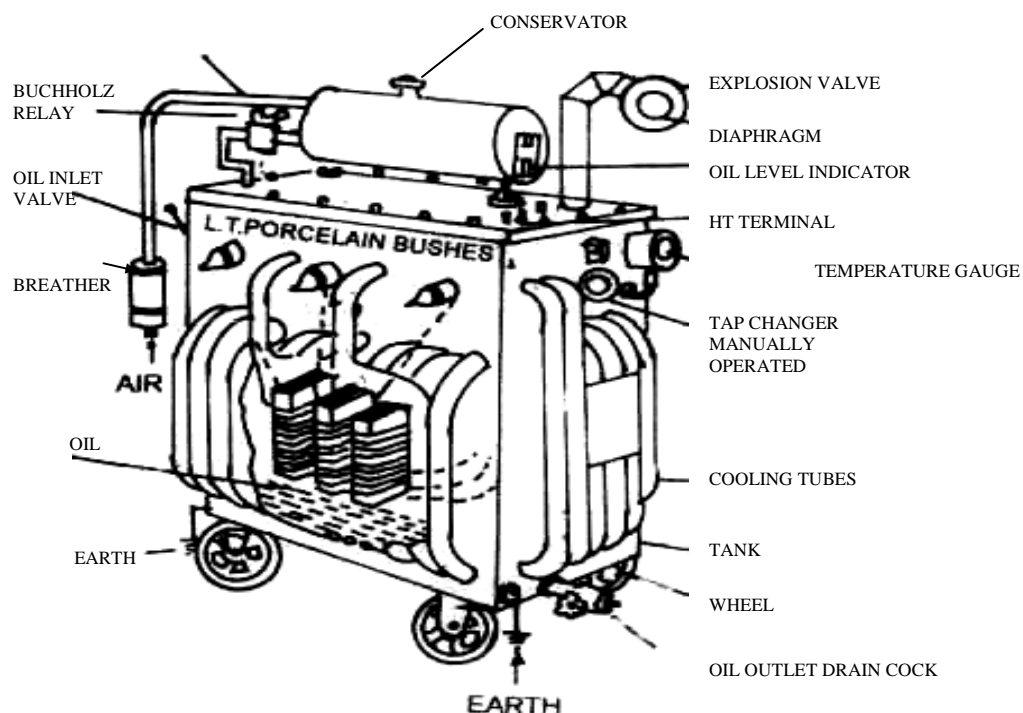


Figure 1.2 3 Phase, 500 kVA, 11/0.433 kV Natural Air Oil Cooled Distribution Transformer



Working of Important Components

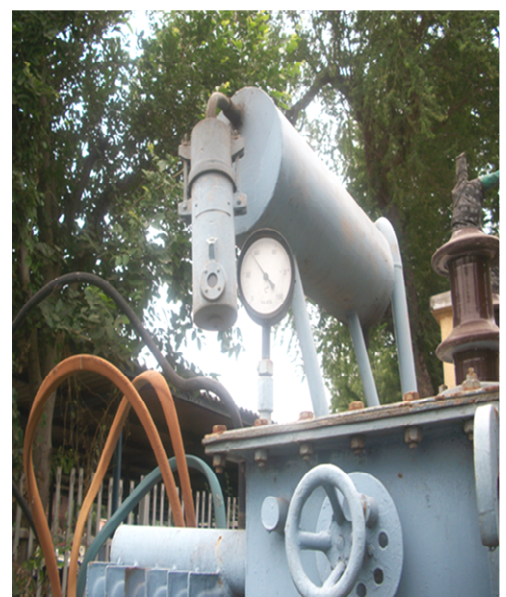
- **Conservator – Equipped with transformer of rating 500 kVA & above**

It is a drum containing transformer oil and mounted at the top of the transformer and connected to the main tank by a pipe. As the volume of oil of transformer tank expands and contracts according to heat produced, this expansion and contraction of oil causes the level of the oil in conservator to rise and fall. The aim of conservator is to

- maintain the oil level in tank
- provide space for the expanded oil.

- **Breather**

It is attached to conservator tank and contains silica gel, which prevents the moist air from entering into the tank during contraction of oil. When oil is hot there is expansion and gas passes to atmosphere through it. When oil is cooled, it contracts and the air enters in it. It prevents transformer oil from moisture contamination.



- **Buchholz Relay**

It is protective relay of transformer. This device signals the fault as soon as it occurs and cuts the transformer out of the circuit immediately. This is gas operated protective relay. It is installed in between the pipe connecting the tank and the conservator. This relay works on the formation of excessive oil vapors or gas inside the transformer tank due to internal fault of transformer. It consists of two operating floats A and B. These are operated by two mercury switches separately provided for each float. The float A is for bell alarm and float B is for operating the tripping circuit.

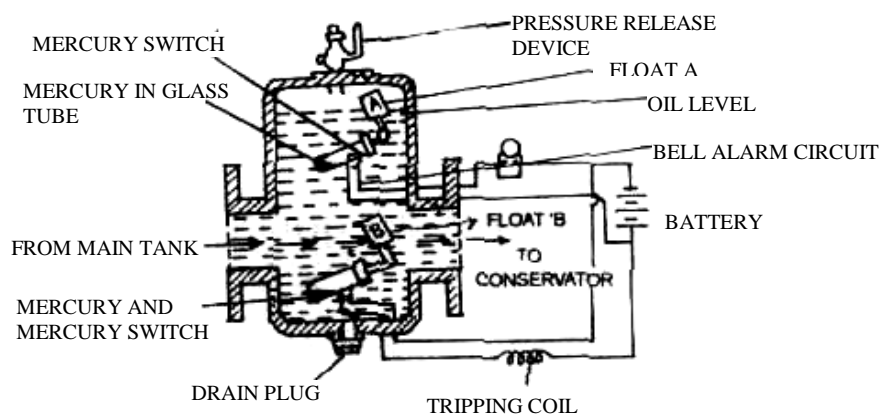


Figure1.3 Buchholz Relay

Whenever there is a minor fault or low level of oil, the bell alarm operated by float 'A' and whenever there is severe fault in the transformer, float 'B' operated due to excessive gases. It trips the circuit breaker and transformer is put out of circuit.

- **Explosion Vent**

A major fault inside the transformer causes instantaneous vaporization of oil, leading to extremely rapid buildup of gaseous pressure. If this pressure is not released within a few milliseconds, the transformer tank can rupture, spilling oil over a wide area. An explosion vent provides instantaneous releasing of such dangerous pressure and protects the transformer.



- **Oil level Indicator**

It indicates level of transformer oil at the conservator of the transformer. It has markings on transparent sheet for maximum & minimum levels.

- **Inlet Valve**

It provides passage to pour the transformer oil in the tank during purification or in case of shortage found in the tank.

- **Outlet Valve**

It provides passage to drain the oil during overhauling or as and when required oil sample for testing.

- **Cooling Tubes**

These tubes provide better and effective cooling of transformer oil by increasing the surface area of tank to the atmosphere.

- **Tape changer**

The tape changer is used to regulate the output voltage manually according to line voltage. The tapes of transformer can be changed by the tape changer manually. It is provided on HV side so that the voltage on LV side feeding to the load can be maintained. Normally tap selection range is $\pm 15\%$ in steps of 2.5% .



1.1.2 Circuit Breaker

The circuit breaker is an equipment which automatically cut off power supply of the system when any fault or short circuit occurs in the system. It detect and isolate faults within a fraction of a second thereby minimizing the damage at the point where the fault has occurred. The circuit breakers are specially designed to interrupt the very high fault currents, which may be ten or more times the normal operating currents.

There are many types of circuit breakers, e.g. Oil, minimum oil, Air blast, Vacuum, SF₆, etc. being used at sub-stations. This list is generally in order of their development and increasing fault rupturing capacity, reliability and maintainability. In distribution sub-station, generally oil circuit breakers and air circuit breakers are used.

1.1.3 Lightning Arrester

Lightning arrester is a most important protective device of distribution sub-station to protect valuable equipment as well as working personnel. It arrests and discharges over voltage to earth during lightning strokes. These are installed between line and earth near equipment.

Representative values of a lightning stroke:

- Voltage - 2×10^8 volts.
- Current - 2×10^4 Amps
- Duration - 10^{-5} seconds.
- Power - 8×10^5 kW

RDSO specification No. TI/SPC/PSI/LCMLA/00030 and TI/MI/0041 Rev 0, for Leakage current monitors may be used for measuring the Third Harmonic Resistive Component (THRC) of leakage current of lightning arresters. These LCM meters are being procured by TRD organisation.

1.1.4 Air Break (AB) Switch/ Isolator

Air break switches are used to isolate equipment for maintenance and also for transfer of load from one bus to another. Lay-out of sub-station depends upon type of Air break switches. These switches are of two types viz. vertical break type or horizontal break type. Horizontal break type normally occupies more space than the vertical break type.

1.1.5 Insulator

The main function of an insulator is to insulate live conductor or equipment at different voltages with reference to the ground structures as well as provide mechanical support. Provision of adequate insulation in a substation is of primary importance from the point of view of reliability of supply and safety of personnel.

1.1.6 Bus Bar Arrangement

The bus bar is a conductor used to connect two and more equipment located side-by-side when the currents are very high. These are usually rectangular, sometimes tubular, bare copper bars supported on insulators. The outdoor bus-bars are either of the rigid type or of the strain type. In the rigid type, pipes are used for making connections among the various equipment. The strain type bus-bars are an overhead system of wires strung between two supporting structures and supported strain type insulators. Since the bus bars are rigid, the clearances remain constant.

1.1.7 Capacitor Bank

It is a series parallel combination of capacitors required to improve power factor of the system. They act as reactive power generators, and provide the needed reactive power to accomplish active power of circuit. This reduces the amount of reactive power, and thus total power (kVA) or the demand. The bank should be provided as near as possible to load.

1.1.8 Earthing

Provision of an effective, durable and a dependable earthing in a substation and switching stations is very important for the safety of operating personnel as well as electrical devices. The voltage levels do not rise above tolerable thresholds and that the earth connection is rugged to dissipate the fault to the earth. Earthing has a very low resistance and connects the electrical equipment to the general mass of the earth. Earthing of various equipment in sub-station is described in chapter 4, para 4.7.

1.1.9 Fencing Arrangement

Fencing is provided at outdoor sub-station yard for restricting entry of unauthorized person and livestock. It must be earthed/ grounded separately. Height of fencing normally should not be less than 1.8 metres. Fencing should be painted once in a year by suitable paint.

1.1.10 Distribution Panel Board

Distribution panel board consists of MCCBs, control equipment, meters and relays are housed in the control room. The panel frame shall be connected to the earth grid by an earthing conductor. A rubber mat of prescribed size and quality shall lay in front of panel.

1.2 GRAVEL/CRUSHED ROCK

In outdoor switch –yard areas are usually covered with about 10cm of gravel of crushed rock of 40 mm size which increases the safety of personnel against shocks, prevent the spread of oil splashes and aids in weed control.

The resistivity of gravel (ρ) is 2000 ohm-meter while that of soil is 100 ohm-meter. Since ρ of gravel is high, only a high voltage can force the current through the body to cause injuries. The gravel act like insulator & throws the electric field generated by GPR back to soil

1.2.1 Advantages of Crushed Rock Used as a Surface Layer

- It provides high resistivity surface layer
- It serves as impediment to the movement of reptiles and thereby help in minimizing the hazards which can be caused by them
- It prevents the formation of pools of oil from oil insulated and oil cooled electrical equipment
- It discourages the growth of weeds
- It helps retention of moisture on the underlying soil and thus helps in maintaining the resistivity of the subsoil at lower value.
- It discourages running of persons in the switchyard and saves them from the risk of being subjected to possible high step potentials.

Chapter 2

MAINTENANCE

The schedule maintenance of equipment installed in sub-station is essential to ensure trouble free service and avoiding un-necessary interruptions.

Following safety precautions should be observed during maintenance of transformers:

- Ensure all arrangements are safe.
- Isolate the transformer from supply and earth the terminals properly.
- Check & record the oil level in the tank before unseal the tank and unscrew the nuts and bolts.
- Ensure the work place is fire proof; care should be taken to prevent fire.
- Put a caution board “NO SMOKING”.
- The staff should not have anything in his breast pocket and should not wear watch or ring.

Item wise activities involved in various schedules of sub-station **equipped with transformers up to 1000 kVA** are as follows:

2.1 DAILY SCHEDULE (If manned)

Items		Schedule Inspection	Action required
Switch yard			
	All jumpers & other connections	Check visually for flash/ spark marks	Tighten the respective bi-metallic clamp/ connection
Transformer			
	Temperature	Check oil temperature during peak load hours. Check ambient temperature	Either switch off some load or share with other transformer
	Tank	Check for oil leakage	Arrest the leakage
	Dehydrating breather	Check visually colour of silica gel	Ensure blue colour of silica gel
Control Panel Room			
	Relays	Check visually target position	Take corrective action
	MCCB/Fuse		
	Load (amp.)	Check against rated figure	Reduce load if higher
	Voltage	Check against rated figure	Take corrective action
	PF meter	Monitor the PF reading	Take corrective action. It should be nearly unity
	General	Ensure general cleanliness of room and panels	
Capacitor Bank			
	All connections	Check visually for flash/ spark marks	Tighten the clamp/ connection

2.2 MONTHLY SCHEDULE

Note: In addition to daily maintenance, carry out following works:

Items		Schedule Inspection	Action required
Switch yard			
	Yard	Growth of unwanted shrubs, garbage etc.	Keep the yard free from shrubs, garbage etc.
	Earth pits	Check neatness and tidiness	Maintain tidiness and do watering
	Earth connections	Check all connection ends at earth pits and metal parts	Ensure solid connection
Transformer			
	Oil level	Check oil level in conservator	If low, top up with dry oil.
	Connections	Open terminal box cover and check connections visually for flash/spark marks	Take corrective action
	Dehydrating breather	Check air passages. Check colour of silica gel	Clear passages, if required. Reactivate silica gel if found pink
	Cleaning	Entire transformer body externally	Clean entire transformer externally including bushings
	Buchholz Relay	Check gas in the chamber	Take corrective action
Control Panel Room			
	Load (amp.)	Check load balancing	If found unbalance, distribute the load equally on all phases
	MCCB/Fuse	Check current ratings	Provide proper size of MCCB/ Fuse according to load condition

2.3 QUARTERLY SCHEDULE

Note: In addition to monthly maintenance, carry out following works:

Items		Schedule Inspection	Action required
Switch yard			
	Support Insulators	Examine for cracks, rust and flash/ spark marks	Clean and replace if required
	Lightning arresters	Check line and earth connection	Clean and ensure rigid connection
	AB switch/ Isolator	Check for proper operation Check line and earth connection	Clean and lubricate Ensure rigid connection
	Jumpers	Check all jumpers	Tighten, if required
	HT bus bars	Examine bus-bar expansion joints etc.	Tighten, if required

Items		Schedule Inspection	Action required
Transformer			
	Bushing	Examine for cracks, rust and flash/ spark marks Check for oil seepage	Clean and replace if required Arrest leakage
Control Panel Room			
	Load (amp.)	Check load balancing	If found unbalance, distribute the load equally on all phases
	MCCB/Fuse	Check condition for overheating	Replace, if required
	LT Bus bars	Check visually for overheating, flash/ spark marks	Take corrective action

2.4 HALF YEARLY SCHEDULE

Note: In addition to quarterly maintenance, carry out following works:

Items		Schedule Inspection	Action required
Transformer			
	Oil	Check BDV	If BDV < 30 kV/cm, do filtration to restore quality of oil.
	Cable box, gasketed joints and gauges	Inspect for leakage and cracks	Take corrective action
Control Panel Room			
	Load (amp.)	Check load balancing	If found unbalance, distribute the load equally on all three phases
	Oil circuit breakers	Check oil level in the tanks. Test the oil, if shows signs of moisture, carbonization or dirt. Check all valves for oil leakage. Check the condition of all gaskets provided to prevent entrance of water and leakage of oil.	Maintain at the proper height. Filter or replace if necessary. Arrest leakage Ensure they are healthy.
	ACB	Check entire unit	Clean with lint free cloth
		Check contacts	Clean fixed and moving contacts
		Operation	Clean and lubricate operating mechanism
		Check tripping of relay	Re-set if required

2.5 YEARLY SCHEDULE

Note: In addition to half yearly maintenance, carry out following works:

Items		Schedule Inspection	Action required
Switch yard			
	Concreting/ coping of the supports	Check the condition of the concreting/ coping of the supports of the structures. The supports fixing to earth become wear and during the time of heavy rains, cyclone or flooding, the structure may fall, leading to a major breakdown.	If there are cracks or the coping of concreting is coming off, preventive action may be taken to concrete or coping.
	Gravel/crushed rock	Check leveling, oil stain and dust accumulation	Spray water to remove oil stain and accumulated dust. Maintain leveling to avoid formation of water pools.
	Earth resistance	Measure the earth resistance of individual equipment earth pit, preferably during summer	If it is beyond permissible limits, take corrective action
	Earth connection of metal parts	Check the earth connection of metal parts to ensure that the metal parts are properly connected to the earth so that any earth fault of the metal parts is cleared quickly and efficiently. If not, accidents may happen.	Take corrective action
	AB switches	Check operation.	Lubricate and ensure proper operation
		Check the line and earth connection of AB switches.	Ensure they are connected properly
	HT lightning arresters	Measure IR value Line-Earth	If low, replace it.
	Connections from and to bus-bars	Check the line and earth connection of HT lightning arresters	Ensure they are connected properly
		Check the connections	Tighten the connections properly from the bus bars and bars to the lines.
	Insulators	Clean and check all insulators for any crack or damage, flash/ spark marks.	Change, if cracks or damages are developing
Transformer			
	Winding	Measure IR value HV-Earth HV-LV LV-Earth	If low, investigate and take corrective action

Items		Schedule Inspection	Action required
	Oil	Check BDV	If BDV < 30 kV/cm, do filtration to restore quality of oil.
		Check for incipient faults	Perform dissolve gas analysis (DGA) as per annexure - B
	Buchholz relay, alarms and their circuits etc.	Check floats, alarm contacts, their operation, fuses etc. Check relay accuracy, etc.	Clean components and replace contacts and fuses if necessary. Change the setting, if necessary.
	Earth resistance	Check values of earth resistance	If high, investigate and take corrective action
	Body	Check for peelings/ rusting/ damage	Repaint, as required
	Cable box	Check the sealing arrangement for filling holes	Ensure sealing arrangement for filling holes

2.6 5 YEARLY SCHEDULE

Note: In addition to yearly maintenance, carry out following works:

Items		Schedule Inspection	Action required
Switch yard			
	Gravel/crushed rock	Check condition, up layer and size	Remove rounded pieces and muck by screening. Maintain up layer of 100 mm by additional quantity of size 40mm
Transformer			
	Conservator	Inspect inside for sludge etc.	Clean or flush inside with oil
	Core and windings	Overall inspection including lifting of core and coils	Wash with clean dry oil.
	Rollers	Examine carefully during overhauling	Grease them properly
	Circuit breaker	Examine carefully during overhauling	Overhaul every circuit breaker completely

2.7 TIPS FOR IMPROVING MAINTENANCE

2.7.1 Transformer

The principal object of transformer maintenance is to maintain the insulation in good condition. Moisture, dust and excessive heat are the main reasons of insulation deterioration and avoidance of these will keep insulation in good condition.

- **Oil**
 - Leakage of excessive oil to be investigated and repaired as early as possible.
 - Maintain the record of oil used and always prefer the same make of oil for topping up or replacement. The oil of different makes may be separated into layers. The mixture of oil have greater tendency to form acidity or sludge.
 - Never use the released oil even if the same make.
 - Never mix the transformer oil to the oil of switchgear equipment.

- Only the dielectric strength does not indicate the healthy condition of oil. Therefore in addition to chemical tests other tests such as acidity test, test for polar contaminants, sludge also to be carried out.
- If the acidity exceeds limits, open the cover to ascertain the condition of interior of tank, core and windings. Take suitable action if sludge or corrosion is evident.
- **DGA : Dissolve Gas Analysis** to assess the internal condition of the transformer.
- **Transformer Body**
 - Ensure correct pressure for tightening the nut and bolt at joints. Replace the gaskets as and when opened the gasketed joints.
 - Measure the insulation resistance without disturbing thing.
 - Properly clean the tank cover before opening it.
 - Remove all nuts and bolts etc. and keep them properly, before removing the cover.
 - Dismount bushings, if mounted on top. Remove the cover carefully if core and windings are separate. If core and windings are suspended from tank cover, provide eye bolts on the cover for lifting along with core and winding. Care should be taken to ensure vertical removal of the core. After lifting the core, recount and tally the spanners and tools used.
 - The spanner should be cleaned and to be held by cotton strap or string tied round the waist or wrist of the staff opening tank cover.
- **Core and Windings**
 - **Lifting the core and coils**
 - Remove the fixing devices if core and coils are suspended, from each end near the top.
 - Unload the connections of bushings and remove the bushings from tank walls.
 - Remove mechanical connection to the tap changing switch handle, if any.
 - Remove any earthing strips between the core clamps and tank.
 - Lift the core and coils vertically by slinging it from lifting lugs provided on core. Make sure that the sling does not foul against connections, tapping switch etc.
 - Allow the core and coils to drain oil into tank for some time.
 - Now lower them on beams placed in a metal tray filled with saw dust or sand.
 - **Inspection**
 - Ensure that everything is intact correctly.
 - Leads are not pulled out off their places.
 - Ensure tightness of nuts and bolts.
 - Clean the sludge by transformer oil and ensure that ducts are not blocked.
 - Clamp the windings firmly without any movement. Adjust the vertical tie bars to tighten loose windings or spacers. Properly tight the special coil adjustment bolt, if provided.
 - Check the proper operation of tap changing switch.
 - Tight all connections.
 - Conduct insulation resistance test and take the corrective action.
 - Remove sludge deposition at the bottom of tank.

- **Bushing**

- Clean the bushing porcelain and examine for cracks and chips. Replace if required.
- If the bushing is below oil level, lower the oil until it is below the bushing hole.
- If only the porcelain is to be changed it may not be necessary to undo the internal bushing connection, for, in some cases the bushing stems are joined by an insulated bar to prevent them from turning when the nuts are undone. All the nuts at the top of the bushing should be removed and the old porcelain lifted straight up over the central stem, which remain in place. Slide the new porcelain down over the stem and tighten the nuts. Too much strain on the porcelain should not be applied when tightening the connections. Change only one porcelain at a time. If the insulated bar between the bushing stems is not provided, the internal connections should be undone and the whole bushing removed before the porcelain is changed and then replace the porcelain.
- When a complete bushing is to be changed the internal connection to the bushing should be undone. If the replacement bushing has a socket at the bottom end, the old bushing should be unclamped and withdrawn from the tank. Now unplug the flexible lead from the old bushing and plugged into the new one, which is then lowered into the hole in the tank and re-clamped firmly but not too tightly.

- **External Connection**

- The bluish tinge characteristic of metal indicates overheating. Either it become loose or dirty or the size of conductor is not suitable for carrying current.
- A small copper loop to bridge the top cover of the transformer and the tank may also be provided to avoid earth fault current passing through the fastening bolts when there is a lightning surge, high voltage surge or failure of bushings.

- **Conservator and Magnetic Oil Gauge**

- The oil level indicator should always be kept clean.
- Replace the broken transparent material of level indicator immediately.
- Examine the mechanism of oil gauge functioning properly during cleaning of conservator.

- **Breather**

There are generally two types of breathers used on a transformer:

- a. Plain breather
- b. Silica gel breather
 - The end of the plain breather should be kept clean and the ventilation holes free of dust. If an oil seal has been provided, the oil should be wiped out.
 - Silica gel dehydrating breathers are fitted with a sight glass so that the colour of the crystals may be seen. The colour changes from blue to pink as the crystals absorb moisture. When the crystals get saturated with moisture they become predominantly pink and should therefore be reactivated. The body of the breather should be removed by undoing the nuts. If the crystals have been kept in an inner container, the container should be removed, but if they are not, the crystals should be removed into a shallow tray. The crystals should be backed at a temperature of about 200°C until the whole mass is restored blue colour. Clean the breather and place the dry and blue crystals. Renew the oil in the sealing cup at the bottom.

- **Buchholtz Relay**
 - During operation if gas is found to be collecting and giving alarm, the gas should be tested and analyzed to find out the nature of fault. Sometimes, it is noticed that the gas collecting is only air. The reasons for this may be that the oil is releasing any absorbed air due to change in temperature or due to leakage on the suction side of pump. The absorbed air is released in initial stages only when no vacuum is applied during filling of oil. The internal faults can be identified to a great extent by a chemical analysis of gas.
 - Routine operation and mechanical inspection/tests should be carried out at one and two yearly intervals respectively.
 - The operation is tested by injecting air into the relay through the lower petcock of a double float relay for the 45° petcock of a single float relay. After inspection, any air which has accumulated in the upper gas chamber must be released by the upper petcock, by filling the chamber with oil.
 - To carry out mechanical inspection, the oil level must be brought below the level of relay. Both floats should be able to rise and fall freely. Relay should give alarm/trip due to the oil level falling below the Buchholtz level. The mercury switches should be tightly clamped. If the glass of a mercury switch is cracked, it must be replaced.
- **Explosion Vent**
 - Frequently inspect diaphragm of the vent and replace if required.
 - An investigation should be carried out to determine the nature and cause of the fault before replacing the broken diaphragm.
- **Gaskets**
 - Check the tightness of all bolts fastening gasketed joints. To avoid uneven pressure, the bolts should be tightened evenly round the joints. Leaking gaskets should be replaced as soon as the circumstances permit.
- **Pipe Work**
 - Inspect the pipe work for leakage due to slack unions, mis-alignment.
 - Align the pipe and remade the joint.
- **Temperature Indicators**
 - At each yearly maintenance inspection, the level of oil in the pockets holding thermometer bulbs should be checked and the oil replenished, if required. The capillary tubing should be fastened down again if it has become loose. Dial glasses should be kept clear and if broken, replaced as soon as possible to prevent damage to the instrument. Temperature indicators should be calibrated with standard thermometer immersed in hot oil bath if found to be reading incorrectly.
- **Spares**
 - It is a healthy practice to have essential spares like one member of each type of bushings, one spare limb winding, one thermometer, one cooling fan, etc, for each group of similar transformer.

2.7.2 Circuit Breakers

Circuit breakers usually need more frequent and more prolonged maintenance. In general, for maintenance of CB the instructions of manufacturer should be followed. A few salient points on maintenance of CB are given below:

Under normal operating conditions during regular inspections following checks should be done:

- The contacts should be checked for proper alignment.
- The oil level should be checked and maintained.
- The oil condition should be tested, if dielectric strength is lower than specified, oil should be filtered. While taking oil samples normal precautions should be followed. If water is found an investigation of the cause should be done and a remedial action should be taken.
- All insulating parts should be thoroughly cleaned to remove all traces of carbon which may remain after the oil has been drained from the tank.
- Check the functioning of the breaker through devices which will have to function on fault or overload.
- Check indicating devices such as mechanical ON and OFF indication, as an incorrect indication may at some times lead to a fatal accident.
- Check auxiliary switches for cleanliness and correct contact making.
- If a CB operate under fault conditions to interrupt a fault, then maintenance after such occurrences should be carried out giving special attention to the following items:
 - Current carrying parts: All contacts including isolator contacts should be examined, dressed or replaced if necessary.
 - Insulation should be cleaned to remove carbon deposits. Examination to be made of cracks, tracking or other damages.
 - Arc control devices should be checked and dismantled, if any carbon or metallic deposits are found, these should be removed.
 - All joints and seal should be examined for tightness.
 - Oil should be checked in case of oil circuit breaker.
 - The general inspection for any mechanical damage or distortion of the structure and mechanism should be made. The switch gear should be closed and tripped by each of the methods provided.

2.7.3 Air Break Switch/ Isolators

The ease of maintenance is mainly a question of access. This is influenced by the method of mounting. Isolators mounted upside down, or with their insulators horizontal often present access problem. During maintenance insulators are cleaned with lintless cloth slightly soaked in gasoline. The conditions of all contacts are checked and on detecting any trace of burning, defective contacts are cleaned or replaced with new ones. Old grease is washed from the insulation rubbing the part with kerosene and a thin layer of fresh grease is applied. Loose bolts and nuts are tightened at all points. The operating mechanism of isolator is checked by closing and opening each isolator several times with the line de-energized.

When adjusting the mechanical part of 3 phase isolators, the switch blades are checked for simultaneous closing isolator blades are checked for ease of engagement with fixed contact jaws.

Isolator contacts must make a close fit in order to avoid excessive heating when closed. This is checked by feeler gauge of 0.05mm (10mm wide). Contact springs are checked both in compressed and free state. Contact surface are coated with acid free petroleum jelly containing minute quantity of graphite.

2.8 MAINTENANCE PROFORMA

2.8.1 Daily Maintenance Proforma

STATION:

LOCATION:

DATE:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	All jumpers & other connections	Check visually for flash/ spark marks		
Transformer			TR - 1	TR - 2
	Temperature	Check oil temperature during peak load hours. Check ambient temperature		
	Tank	Check for oil leakage		
	Dehydrating breather	Check visually colour of silica gel		
Control Panel Room				
	Relays	Check visually target position		
	MCCB/Fuse	Check for overheating		
	Load (amp.)	Check against rated figure		
	Voltage	Check against rated figure		
	PF meter	Monitor the PF reading		
Capacitor Bank				
	All connections	Check visually for flash/ spark marks		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

2.8.2 Monthly Maintenance Proforma

STATION:

LOCATION:

DATE:

Note: In addition to daily maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	Earth pits	Cleaning		
		Watering		
	Earth connections	Check all connections both at earth pits and metal parts		
	Yard	Growth of unwanted shrubs, garbage etc. Keep the yard free from shrubs, garbage etc.		
Transformer			TR - 1	TR - 2
	Buchholz Relay	Check gas collection		
	Oil level	Check oil level in conservator		
	Connections	Open terminal box cover and check connections visually for flash/ spark marks		
	Dehydrating breather	Check air passages		
		Check colour of silica gel		
	Cleaning	Clean entire transformer externally		
Control Panel Room				
	Load (amp.)	Check load balancing. If found unbalance, distribute the load equally on all phases		
	MCCB/Fuse	Provide proper size of MCCB/Fuse according to load condition		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

2.8.3 Quarterly Maintenance Proforma

STATION:

LOCATION:

DATE:

Note: In addition to monthly maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	Support Insulators	Clean and examine for cracks		
	Lightning arresters	Clean and check line and earth connection		
	AB switch	Clean and lubricate for proper operation		
		Check line and earth connection		
	Jumpers	Check and tighten all jumpers		
	HT bus bars	Examine and tighten bus-bar expansion joints etc.		
Transformer			TR - 1	TR - 2
	Bushing	Clean and examine for cracks		
		Check for oil seepage		
Control Panel Room				
	LT Bus bars	Clean and check visually for overheating, flash/ spark marks. Tighten all connections.		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

2.8.4 Half Yearly Maintenance Proforma

STATION:

LOCATION:

DATE:

Note: In addition to quarterly maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any				
Transformer			TR - 1		TR - 2		
	Oil	Check BDV, if BDV < 30 kV/cm, do filtration to restore quality of oil.					
	Cable box, gasketed joints and gauges	Inspect for leakage and cracks					
Control Panel Room							
	Oil circuit breakers		OCB1	OCB2	OCB3	OCB4	OCB5
		Check oil level in the tanks.					
		Test the oil, if shows signs of moisture, carbonization or dirt. Filter or replace if necessary.					
		Check all valves for oil leakage.					
		Check the condition of all gaskets provided to prevent entrance of water and leakage of oil.					
	ACB		ACB 1	ACB 2	ACB 3	ACB 4	ACB 5
		Clean with lint free cloth					
		Clean fixed and moving contacts					
		Clean and lubricate operating mechanism					

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

2.8.5 Yearly Maintenance Proforma

STATION:

LOCATION:

DATE:

Note: In addition to half yearly maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	Concreting/ coping of the supports	Take preventive action, if there are cracks or the coping of concreting is coming off.		
	Gravel/crus hed rock	Check leveling, oil stain and dust accumulation. Spray water to remove oil stain and accumulated dust. Maintain leveling to avoid formation of water pools.		
	Earth resistance	Measure the earth resistance of individual equipment earth pit <ul style="list-style-type: none">Major sub-station : 1.0 ohmsSmall sub-station : 2.0 ohms		
	Earth connection of metal parts	Check the earth connection of metal parts is properly connected to the earth.		
	AB switches	Check the line and earth connections		
		Lubricate and check proper operation		
	HT lightning arresters	Measure IR value between HV terminal and earth, if low, replace it.		
	Bus-bars	Check the line and earth connection Tighten the connections properly from the bus bars and bars to the lines		
	Insulators	Clean and check all insulators for any crack or damage. Change if required		
Transformer			TR - 1	TR - 2
	Winding	Measure IR value between HV-Earth HV-LV LV-Earth If low, take corrective action		
	Oil	Check BDV, if < 30 kV/cm, do filtration to restore quality of oil.		
		Perform dissolve gas analysis (DGA) as per annexure - B to check for incipient faults		

Items		Work to be done	Work done/ Remark if any	
	Buchholz relay	Clean and check components of floats, alarm contacts and their operation. Replace if necessary		
		Check accuracy of relay. Change the setting, if necessary.		
	Earth resistance	Check earth resistance of neutral and body. If high, take corrective action		
	Body	Check for peelings/ rusting/ damage. Repaint, as required		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

2.8.6 5 Yearly Maintenance Proforma

STATION:

LOCATION:

DATE:

Note: In addition to yearly maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	Gravel/crushed rock	Check condition, up layer and size. Remove rounded pieces and muck by screening. Maintain up layer of 100 mm by additional quantity of size 40mm		
Transformer			TR - 1	TR - 2
	Core and windings	Overall inspection including lifting of core and coils. Wash with clean dry oil.		
	Rollers	Examine carefully during overhauling and grease them properly		
Control Panel				
	Circuit breaker	Overhaul every circuit breaker		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

CHAPTER 3

TROUBLE SHOOTING

Failure of equipment in Substation is not a sudden phenomenon, for that matter each and every failure will take place only after alerting through some pre-signs. If they went unnoticed or unattended will results into a failure. Therefore it is wise on the part of the maintenance personnel to act upon the pre failure signs noticed well in advance to keep the equipment failure free and serviceable at all times.

If new equipment is installed for which there is no past experience, it will be difficult to forecast the defects and probable failures. Further if a failure occurred even though all the known precautions were observed, then it is necessary and more advantageous to investigate into the failure in such a manner to pull out the actual reasons of failure so that action shall be initiated to avoid recurrence.

3.1 AN APPROACH TO EQUIPMENT FAILURE INVESTIGATION

3.1.1 On Failure Aspects

1. Occurrence
2. Date of occurrence
3. Past similar occurrences if any
4. Analysis of failure i.e. why did it happen?
5. Whether the rate of failure is worse than other installations?

3.1.2 On Maintenance Aspects

1. Whether schedule maintenance & required testing have been carried out on the failed equipment as per norms stipulated?
2. Does the frequency of maintenance require change?
3. Was the work properly supervised?
4. Was any RDSO modification required to be done?
5. Is any modification possible to avoid failure?

3.1.3 About Staff

1. Is the quality of work done satisfactorily?
2. Is the skilled staff properly trained to carry out the work?
3. Is the SMI available with them?
4. Are proper tools available with the staff?

3.1.4 About Material

1. Is the material received from approved source?
2. Whether the material is as per approved specification?
3. Can a better material be used?

3.1.5 About Testing

1. Is the testing equipment available?
2. Could testing procedure be improved to weed out the failures?
3. Whether testing equipment are calibrated?

3.1.6 General Points

Whether following points were checked / performed properly?

1. Proper contact
2. Clearances
3. Capacity
4. Proper contact pressure
5. Crack detections
6. Cleaning
7. Proper connections/alignment
8. Cross checks/super checks

3.1.7 Any other Findings not covered in the above

3.2 CAUSES OF FAILURES AND THEIR REMEDIES

3.2.1 Common Failures of Transformer

Some of the common failures/ defects occurred in transformer are as under:

- Oil leakage
- Low BDV
- Bushing failure
- Winding failures
- Excessive overheating of oil
- Low IR value
- Humming sound

➤ Oil leakage

Location	Possible causes	Remedial action
From screw joints	<ul style="list-style-type: none"> - Foreign material in threads - Poor threads - Improper assembly 	<ul style="list-style-type: none"> - Remove the foreign material. - Check the threads & replace if required. - Ensure proper assembly.
From gasket joints	<ul style="list-style-type: none"> - Insufficient or uneven compression. - Improper preparation of gaskets and gasket surfaces. - Old gaskets 	<ul style="list-style-type: none"> - Tight gasket joints uniformly. - Provide proper gaskets. - Provide new gaskets.
From weld joints	<ul style="list-style-type: none"> - Shipping strains, imperfect weld. 	<ul style="list-style-type: none"> - Repair welds following proper procedure.

Location	Possible causes	Remedial action
From couplings & their joints	<ul style="list-style-type: none"> - Cracks in couplings. - Defective coupling joints. 	<ul style="list-style-type: none"> - Replace couplings and secure the pipe lines near couplings properly. - Make proper coupling joints and tight the screws.
From drain plugs.	<ul style="list-style-type: none"> - Defective thread portion. - Defective oil seal. 	<ul style="list-style-type: none"> - Check the threaded portion. - Replace the oil seal and tight the drain plug.

➤ **Low BDV**

Type of failure	Possible causes	Remedial action
Low BDV	Moisture contamination in transformer oil due to inactive silica gel (pink colour).	Reactivate silica gel crystals or replace them. Purify the transformer oil to restore dielectric strength.
	Leaks around cover accessories, breathing air from leaks.	Attend leaks, replace gasket if necessary. Purify the transformer oil to restore dielectric strength.
	Humid atmosphere in rainy season.	Purify the transformer oil to restore dielectric strength and check the BDV & water content.

➤ **Bushing Failure**

Types of failure	Possible causes	Remedial action
H V Bushing flash over	<ul style="list-style-type: none"> - Lightning discharge or over voltage - Dirty bushing. 	<ul style="list-style-type: none"> - It may be a break in the turns or end lead, flash marks on the end coil and earthed parts close to it. - Ensure cleaning of porcelain bushing during each inspection.
H V Bushing porcelain insulator petticoat broken / cracked.	<ul style="list-style-type: none"> - External hitting. 	<ul style="list-style-type: none"> - Ensure proper cleaning and visual checking of porcelain bushing during each inspection.

➤ **Winding Failures**

Types of failure	Possible causes	Remedial action
Primary winding lead open circuited / earthed.	Due to overload or brazing failure.	Check the winding in one or all phases would show signs of overheating and charring.
Bulging and inter turn short, inter layer short or inter coils short.	Coils shrink and in between insulation failure.	Investigate for over loading and take corrective action accordingly.
Shorting between LV and HV coils.	Insulation failure.	During manufacturing/ rewinding of the transformer, the coils should be pressed down, heated and cooled repeatedly until the coil height stabilizes.
Flash mark on the core and support.	Dead short-circuit due to lateral or displacement of the coil. - Winding loose on the core.	- Nomex paper insulation sheet should be provided between H.V. & L.V. coils so as to strengthen the insulation level. Ensure that this insulation sheet does not cause any obstruction in the passage of oil flow. - Replace the transformer and core to be lifted for thoroughly checking and take corrective action accordingly. - Repair the winding if possible

➤ **Excessive overheating of transformer**

Type of failure	Possible causes	Remedial action
Temperature rise of transformer oil.	- Any internal fault such as short circuited core, core bolts/ clamps insulation failure etc. - Low oil level in conservator. - Slugged oil. - Overloading	- Replace the transformer and core to be lifted for thoroughly checking. Take corrective action according to observations and oil test report. - Check the oil level in conservator and top up if required. - Carry out purification of oil to remove sludge. - Adjust the load

➤ **Low IR value**

Type of failure	Possible causes	Remedial action
Low IR value	- Moisture in oil.	- Purify the oil with high vacuum type oil purification plant and test the oil for electrical strength and water content.
	- Insulation failure between winding and core.	- Replace the transformer. Lift the active part and check the winding thoroughly for insulation damage and take corrective action accordingly.
	- Internal connection leads insulation damage.	- Check the internal connection leads by lifting the active part and re-tape insulation paper of damaged portion.
	- Weak brazing	- Clean the joint and braze properly.

➤ **Humming sound**

Type of failure	Possible causes	Remedial action
Humming sound	- Loose core	- Lift the active part and tight all the pressure bolts and clamping bolts.
	- Winding loose due to shrinkage of coils.	- During manufacturing/ rewinding of the transformer, the coils should be pressed down, heated and cooled repeatedly until the coil height stabilizes.
		- The winding pressure bolts and core clamping bolts should be tightened during the first POH after commissioning to take care of shrinkage.

3.3 INVESTIGATION INTO CAUSES OF FAILURES OF TRANSFORMER

In most cases the causes of the fault can be surmised by careful observation of the condition of windings, e.g. displacement of the turns or coils, coil insulation (brittle or healthy), evidence of overheating, carbon deposit or flash marks on the core, supports, the inner surface of the tank or cover. The following notes may be helpful in identifying the causes:

3.3.1 Failure due to Lightning Discharge or Over Voltages

This is characterized by break down of the end turns close to the line terminal. There may be a break in the turns or end lead, and also flash marks on the end coil and earthed parts close to it, but the rest of the coils will be found to be healthy.

3.3.2 Sustain Overloads

The windings in one or all phases would show signs of overheating and charring; the insulation would be very brittle and would have lost all its elasticity.

3.3.3 Inter-turn short, Inter-layer short, or Inter coils short

The same signs as for indicated for sustained over load would be noticed, but only on affected coils, the rest of the coils being intact. This is likely if the differential relay or the Buchholz relay has operated.

3.3.4 Dead Short-circuit

This can be identified by the unmistakable, lateral or axial displacement of the coils. The coils may be loose on the core, some turns on the outermost layer may have burst outwards and broken as if under tension. If, in addition to these signs, the windings are also completely charred, it is conclusive evidence that the short circuit has continued for an appreciable period, not having been cleared quickly by the protective relays.

3.3.5 Buchholz Relay Tripping

If the upper chamber of the Buchholz relay alone has tripped, check the insulation of core bolts, by applying a voltage of 230V to 1000V between the core and each bolt. If it fails, renew the insulating bush. Observe also all the joints, and tap-changer contacts, for over-heating and arcing.

3.3.6 Internal Flashover

If the oil shows a low BDV, it does not necessarily mean it has caused the breakdown. At high voltage ratings, excessive moisture content in the oil may result an internal flashover between the live parts and earth, which all leave corresponding tell tale marks.

3.4 DO's & DON'Ts

3.4.1 Do's

1. Ensure all safety arrangement while working on electrical installation.
2. Ensure that all tools & tackles are in good & working condition.
3. Check and thoroughly investigate the transformer whenever any alarm or protection is operated.
4. Check the protection system periodically.
5. Ensure every employee is familiar with the instructions for restoration of persons suffering from electric shock.
6. Trained the staff in operating the fire-fighting equipment.
7. Always avoid un-balance loading on phase.
8. Do earthing of all points before starting maintenance.
9. Keep all spares away from dirt.
10. Work with full confidence.
11. Ensure thorough and full cleaning of insulators, since partial cleaning is worse than no cleaning.
12. Ensure perfect isolation of supply before commencement of maintenance work.
13. Put a caution board when on work.

3.4.2 Don'ts

1. Don't use low capacity lifting jacks on transformer.
2. Don't leave circuit tap switch unlock.
3. Don't leave any loose connection.
4. Don't meddle with protection system.
5. Don't allow conservator oil level to fall below minimum level mark of indicator.
6. Don't parallel transformers which do not full fill the necessary requirement.
7. Don't allow unauthorised entry in the sub-station.
8. Don't overload the transformer other than the specified limit mentioned.
9. Don't tight the nuts & bolts in excess to arrest any leakage.
10. Don't avoid any unusual noise/occurrence noticed in the substation..
11. Never use fuses higher than the prescribed ratings on HT and LT sides.
12. Earthing connections should never be done in loose manner. Simply twisting of GI wires would be dangerous. The earthing connections should as far as possible be done by using continuous wire or providing suitable connectors. It should be ensured that these connections are tightened rigid.
13. Never keep the breather pipe open or exposed.
14. Don't ignore safety rules during maintenance work.

Chapter 4

EARTHING

Provision of adequate earthing in a substation and switching stations are very important for the safety of operating personnel as well as electrical devices do not rise above tolerable thresholds and that the earth connection is rugged to dissipate the fault to the earth. The importance of an effective, durable and a dependable earth for ensuring safety from electrical hazards does not require to be elaborated upon more. By earthing, connecting the electrical equipment to the general mass of the earth, this has a very low resistance.

4.1 PURPOSE OF SUBSTATION EARTHING SYSTEM

The object of an earthing system in a substation is to provide under and around the substation a surface that shall be at a uniform potential and near zero or absolute earth potential as possible. The provision of such a surface of uniform potential under and around the substation ensure that no human being in the substation subject in shock of injury on the occurrence of a short circuit or development of other abnormal conditions in the equipment installed in the yard.

The primary requirements of a good earthing system in a substation are:

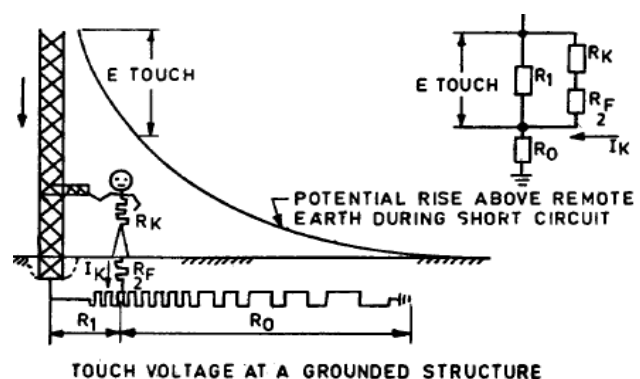
- It is stabilize circuit potentials with respect to ground and limit the overall potential rise.
- It is protect life and property from over voltage.
- It is provide low impedance path to fault currents to ensure prompt and consistent operation of protective devices during ground faults.
- It is keep the maximum voltage gradient along the surface inside and around the substation within safe limits during ground fault.

4.2 MAXIMUM PERMISSIBLE RESISTANCE OF EARTHING SYSTEM

- | | | |
|---|---|-----------|
| ▪ Large power station | : | 0.5 ohms. |
| ▪ Major sub-station | : | 1.0 ohms. |
| ▪ Small sub-station | : | 2.0 ohms. |
| ▪ In all other cases | : | 8.0 ohms. |
| ▪ The earth continuity inside an installation | : | 1.0 ohms. |

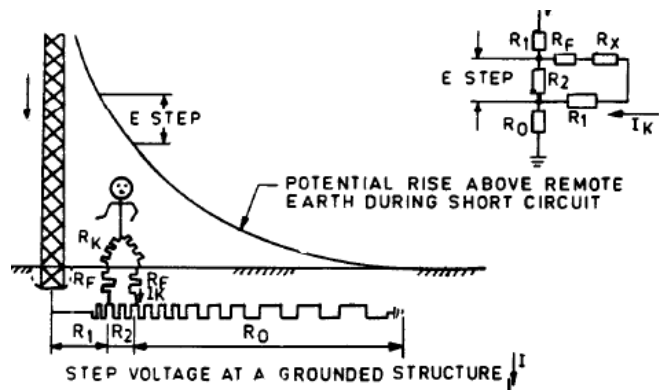
4.3 TOUCH VOLTAGE (E TOUCH)

The potential difference between a ground metallic structure and a point on the earth's surface separated by a distance equal to the normal maximum horizontal reach of a person, approximately one meter as shown in figure.



4.4 STEP VOLTAGE (E STEP)

The potential difference between two points on the earth surface separated by distance of one pace that will be assumed to be one meter in the direction of maximum potential gradient as shown in figure.



4.5 EARTHING SYSTEM IN SUB STATION

The earthing system comprises of earthing (or) grid, earthing electrodes, earthing conductors and earth connections.

4.5.1 Earth Mat or Grid

The primary requirement of earthing is to have a very low earth resistance. If the individual electrodes driven in the soil are measured it will have a fairly high resistance. But if these individual electrodes are inter linked inside the soil, it increases the area in contact with soil and creates a number of parallel paths and hence the value of earth resistance in the interlink state, which is called combined earth resistance, will be much lower than the individual resistance.

However interlinking of earth pit electrodes is necessary. The sub-station involves many earthing through individual electrodes. In order to have uniform interconnection, a mat or grid or earthing conductor is formed inside the soil. Thus a mat is spread underneath the sub-station. Hence if a ground electrode is driven in the soil, the interlinking can be done by a small link between that electrode and earth mat running nearby. The spreading of such a mat in the soil also ensures the object of earthing that the surface under and around the sub-station is kept at as nearly absolute earth potential as possible.

4.5.2 Construction of Earth Mat

The sub-station site including the fence is segregated at intervals, of say four meters width along with length and breadth wise. Trenches of one meter to 1.5 meter depth and one meter width are dug along these lines. The earthing conductors of sufficient sizes (as per fault current) are placed at the bottom of these trenches. All the crossings and joints are braced. The trenches are then filled up with soil of uniform fine mass of earth mixed with required chemicals depending upon the soil resistivity.

If location of equipment is fixed, the intervals are also arranged that the earth mat passes nearby the equipment location to facilitate for easy interlinking.

It is preferable to extend the mat beyond the fence for about one meter so that the fence can also be suitably earthed and made safe for touching.

Normally the earth mat is buried horizontally at a depth of about half a meter below the surface of the ground and ground rods are at suitable points.

4.5.3 Earth Mat in a Sub-Station

Earth Mat is connected to the Following in a Sub-Station:

- The neutral point of such system through its own independent earth.
- Equipment frame work and other non-current carrying parts of the electrical equipments in the sub-station.
- All extraneous metallic frame work not associated with equipment.
- Handle of the operating pipe.
- Fence if it is within 2 m from earth mat.

4.6 LOCATION OF EARTH ELECTRODE

The location of earth electrode should be chosen in one of the following types of soil in the order of preference given on next page

- Wet marshy ground.
- Clay, loamy soil and arable land
- Clay and loam mixed with varying proportions of sand, gravel and stones.
- Damp and wet sand, peat.

Dry sand, gravel chalk limestone, granite, very stone ground and all locations where virgin rock is very close to the surface should be avoided.

4.6.1 Pipe Electrode

It should be made of 'B' class G.I pipe. The internal diameter should not be smaller than 38 mm and it should be 100 mm fore cast Iron pipe. The length of the pipe electrode should not less than 2.5 m. It should be embedded vertically. Where hard rock is encountered it can be inclined to vertical. The inclination shall not more than 30° from the vertical.

To reduce the depth of burial of an electrode without increasing the resistance, a number of pipes shall be connected together in parallel. The resistance in this case is practically proportional to the reciprocal of the number of electrodes used so long as each is situated outside the resistance area of the other. The distance between two electrodes in such a case shall preferably be not less than twice the length of electrode as shown in figure 4.1.

4.7 EARTHING OF VARIOUS EQUIPMENT IN THE SUB-STATION

4.7.1 Isolators and switches

A flexible earth conductor is provided between the handle and earthing conductor attached to the mounting bracket and the handle of switches is connected to earthing mat by means of two separate distinct connections made with MS flat. One connection is made with the nearest longitudinal conductor, while the other is made to the nearest transverse conductor of the mat.

4.7.2 Lightning Arrestors

Conductors as short and straight as practicable to ensure minimum impedance shall directly connect the bases of the lightning arrestors to the earth grid. In addition, there shall be as direct a connection as practicable from the earth side of lightning arrestors to the frame of the equipment being protected.

Individual ground electrodes should be provided for each lightning arrestor for the reason that large grounding system in itself may be relatively of little use for lightning protection. These ground electrodes should be connected to the main earth system. In the case of lightning arrestors mounted near transformers, earthing conductor shall be located clear off the tank and coolers in order to avoid possible oil leakage caused by arcing.

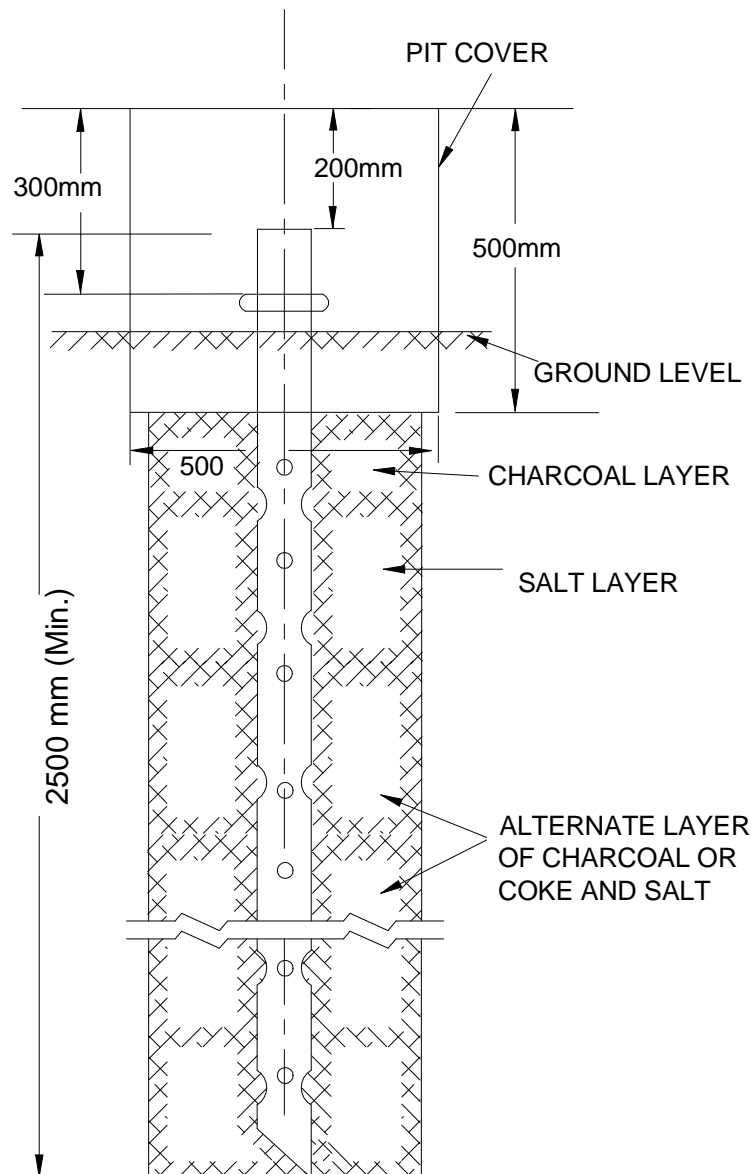


Figure –4.1 Pipe Electrode

4.7.3 Circuit Breakers

For every breaker there will be five earth connections to the earth mat with MS flat (i) breaker body (ii) relay panel (iii) CTs of the breaker (iv) Two side of the breaker structure.

4.7.4 Transformers

The tank of each transformer shall be directly connected to the main grid. In addition there shall be as direct a connection as practicable from the tank to the earth side of projecting lightning arrestors.

The transformer track rails shall be earthed either separately or by bonding at each end of the track and at intervals not exceeding 60.96 meter (200 feet). The earthing of neutral bushing shall be by two separate strips to the earth grid and shall likewise be run clear to rank cell and coolers.

4.7.5 Current Transformers and Potential Transformers

The supporting structures of Current Transformer and Potential Transformer unit of bases, all bolted cover plates to which the bushings are attached connected to the earthing mat by means of two separate distinct connections made with MS flat. One connection is made with the nearest longitudinal conductor, while the other is made to the nearest transverse conductor of the mat.

4.7.6 Other Equipment

All equipment's, structures, and metallic frames of switches and isolators shall be earthed separately as shown in figure 4.2.



Figure –4.2 Structure Earthing

4.7.7 Fences

The Sub-station fence should be generally too far outside the substation equipment and grounded separately from the station ground. The station and the fence ground should not be linked. To avoid any risk to the person walking near the fence inside the station, no metal parts connecting connected to the station ground, should be near to the fence five feet and it is desirable to cover the strip about ten feet wide inside the fence by a layer of crushed stone which keeps its high resistivity even under wet condition. If the distance between the fence and station structures, cannot be increased at least five feet and if the fence is too near the substation equipment structure etc., the station fence should be connected to the fence ground, otherwise a person touching the fence and the station ground simultaneously would be subjected to a very high potential under fault conditions.

In a fence very near to the station area, high shock voltage can be avoided by ensuring good contact between the fence stations and by grounding the fence at intervals. The station fence should not be connected to the station ground but should be grounded separately. If however, the fence is close to the metal parts of substation, it should be connected to the station ground.

4.7.8 Ground Wire

All ground wires over a station shall be connected to the station earth grid. In order that the station earth potentials during fault conditions are not applied to transmission line ground wires and towers, all ground wires coming to the station shall be broken at and insulated on the station side of the first tower or pole external to the station by means of 10" disc insulator.

4.7.9 Cables and Supports

Metal sheathed cables within the station earth grid area shall be connected to that grid. Multi-core cables shall be connected to the grid at least at one point. Single core cables normally shall be connected to the grid at one point only. Where cables which are connected to the station earth grid pass under a metallic station perimeter fence, they shall be laid at a depth of not less than 762 mm (2'-6") below the fence, or shall be enclosed in an insulating pipe for a distance of not less than 1524 mm (5') on each side of the fence.

4.7.10 Panels and Cubicles

Each panel or cubicle should be provided near the base with a frame earth bar of copper to which shall be connected the metal bases and covers of switches and contactor unit. The frame earth bar shall in turn be connected to the earth grid by an earthing conductor.

4.8 DISTRIBUTION TRANSFORMER STRUCTURE EATHING

1. For earthing three earth pits in triangular formation at a distance of six meter from each other are to be provided.
2. Earth pit should be digged for 45 cm x 45 cm size and 5 ft. depth.
3. 3 Nos. of 40 mm dia and 2.9 mm thickness and 3 mts. (10 ft) length of earth pipe should be used for earthing. This earth pipe is erected in 5 ft. depth earth pit and for the balance length of earth pipe is driven by hammering into the ground.
4. When a pipe is driven into the earth, the earth surrounding the pipe can be considered to be consisting of concentric cylinders of earth which will be bigger in size and area, as they are away from the pipe. The current can travel into the earth with large area having little resistance.
5. 3 m. length of electrode will have contact with the earth area of 3 m in radius. Hence to have better effect 3 m pipe should be fixed at a distance of 6 m (i.e.) twice the distance of pipe length.
6. For better earth connection, one G I clamp should be welded to the earth pipe and the other clamp bolted with 2 nos. 11/2 x 1/2 G I bolt nuts and 4 nos. G. I. washers to the earth pipe.
7. Two separate distinct connections through G I wire should be made from the transformer neutral bushing to the earth pit No. 2.
8. Two separate distinct connections through GI wire should be made from the transformer HT lightning Arrestor to the earth pit No. 1. As far as possible this earth wire should not have contact with other earth wire connections. If needed PVC sleeves can be used for insulation.
9. Two separate distinct connections through GI wire from the following parts of the structure should be made to the earth pit No. 3 as shown in figure- 16.
 - Metal part of the disc and stay.
 - Top channel.
 - AB switch frame, metal part of the insulator, side Arms.
 - HG fuses frame and metal part of the insulator.
 - LT cross arm, metal part of the insulator, open type fuse frame.
 - AB switch guide and operating pipe (At the top and bottom)

- Transformer body.
- Belting angle.
- Seating channel
- LT lightning arrestor.

The above earth connections should be made as far as possible without joints. Wherever joints are necessary, GI sleeves should be used by proper crimping.

10. The earth pits No. 2 and 3 can be interlinked to serve as parallel path and lower the earth resistance.
11. If the earth resistance of the earth pit No. 1 is high, then another earth pit No. 4 can be formed as a counter poise earth and linked with the HT lightning arrestor pit.

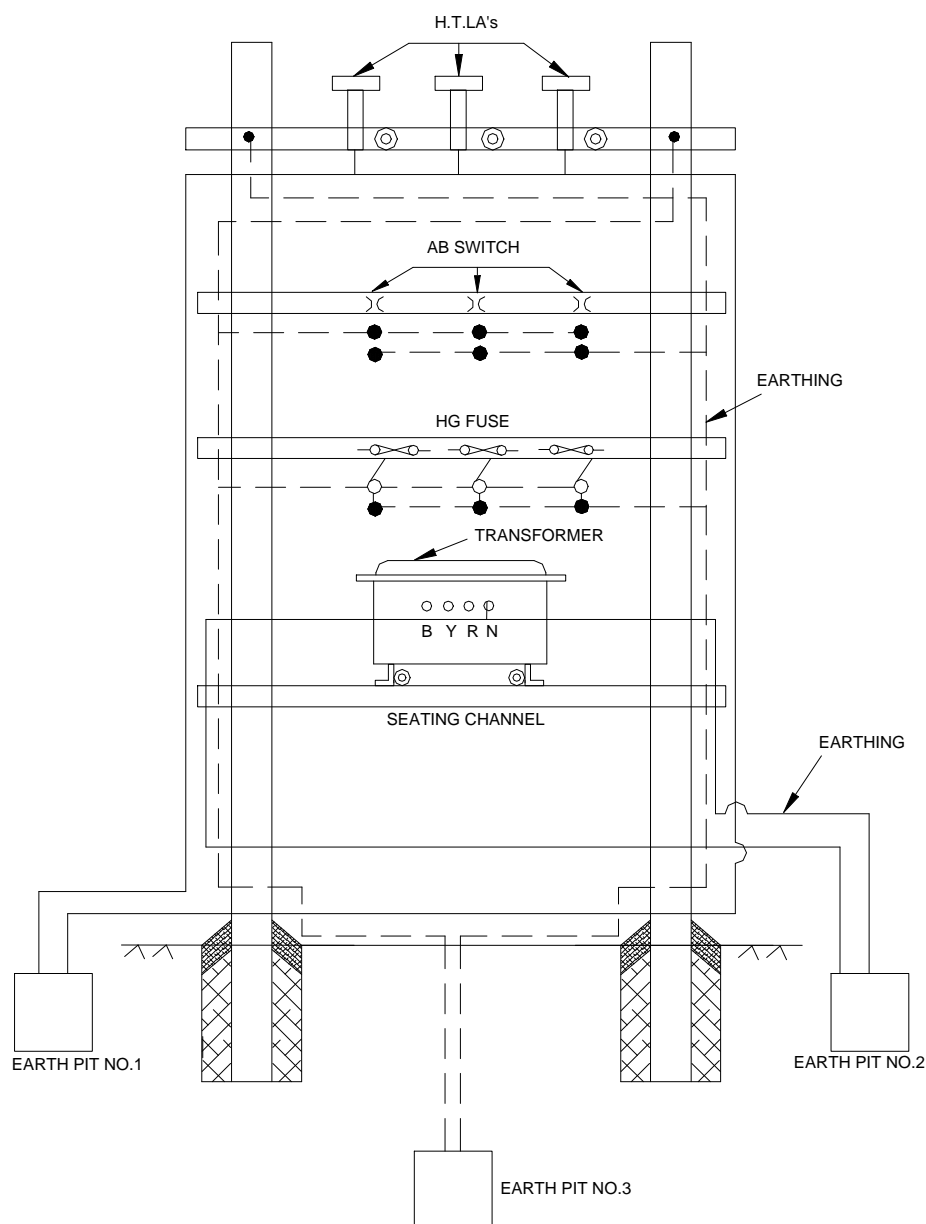


Figure 4.3: Earthing of Distribution Transformer Structure

4.9 TESTING OF EARTHING SYSTEM

4.9.1 Measurement of Earth Electrode Resistance

- **Fall of potential method**

In this method two auxiliary earth electrodes, besides the test electrode, are placed at suitable distances from the test electrode as shown in figure 4.4. A measured current is passed between the electrode 'A' to be tested and an auxiliary current electrode 'C' and the potential difference between the electrode 'A' and the auxiliary potential electrode 'B' is measured. The resistance of the test electrode 'A' is then given by:

$$R = V/I$$

Where, R = Resistance of the test electrode in ohms,

V = Reading of the voltmeter in volts,

I = Reading of the ammeter in amperes

In most cases, there will be stray currents flowing in the soil and unless some steps are taken to eliminate their effect, they may produce serious errors in the measured value. If the testing current is of the same frequency as the stray current, this elimination becomes very difficult. It is better to use an earth tester incorporating a hand driven generator. These earth testers usually generate direct current, and have rotary current reverser and synchronous rectifier mounted on the generator shaft so that alternating current is applied to the test circuit and the resulting potentials are rectified for measurement by a direct reading moving coil ohm meter. The presence of stray currents in the soil is indicated by a wandering of the instrument pointer, but an increase or decrease of generator handle speed will cause this to disappear.

At the time of test, where possible, the test electrode shall be separated from the earthing system. The auxiliary electrode consists of 12.5 mm diameter mild steel rod driven up to one meter into the ground.

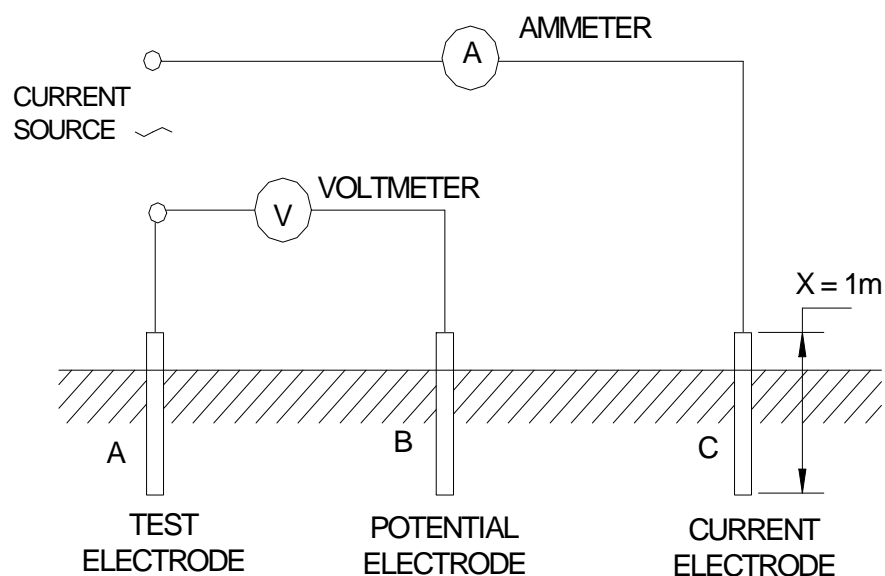


Figure 4.4: Fall of potential method

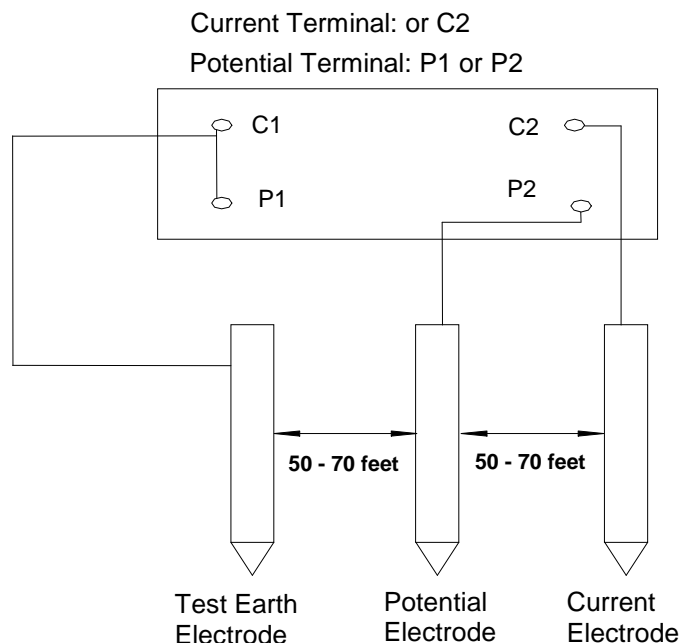
4.9.2 Details of Earth Tester (Hand Driven)

Earth resistance meter are employed for measurements of earth resistance in substation and other electrical installations. An Earth resistance meter comprises a hand driven magneto type D.C. Generator, a current reverser, rotary rectifier and ohm meter.

The current reverser and rotary rectifier are driven along with D.C. Generator by driving systems which incorporate a clutch mechanism for unidirectional rotation and a governor for speed control. The function of current reverser is to change the direction of flow of current in the soil and that of rotary rectifier is to maintain unidirectional current in the potential coils of the ohm meter.

The ohm meter consists of a current coil and a potential coil mounted on a common spindle and placed in the magnetic field of a permanent magnet. The current coil is connected in series with the earth electrodes and current electrodes. The potential coil is connected across the earth electrode and the potential electrode through the rotary rectifier. While measuring the earth resistance the terminals C1, P1 are connected to the main earth electrode P2 to the potential electrode and C2 to the current electrode. The potential and current electrodes are temporary electrodes placed in the ground 50 to 75 feet apart and 50 to 75 feet & from the earth electrode as shown in below figure 4.5.

When the megger is operated an ac current is produced in the coil. The voltage drop produced in the earth electrode is applied across the potential coil. The current coil produces a torque in the clock wise direction, and the potential coil produces a torque in anti-clock wise direction. The current applied to the current coil is inversely proportional to the earth resistance and the voltage drop applied across the potential coil is directly proportional to the earth resistance the torque opposes each other and brings the moving system to rest when they are equal. The pointer indicates the earth resistance values on a calibrated scale.



4.10 MAINTENANCE FREE EARTHING

In conventional earthing system GI pipe is used as earth electrode. It is provided with charcoal and salt as conducting media, which provides a reasonable earth. Corrosion of metallic parts is comparatively fast. It also requires maintenance by way of watering of earth pits and chiseling of corrosion prone parts and replacement. It also requires monitoring which may not always be feasible in certain crowded and inaccessible areas.

With technological developments in this field, modern maintenance free and durable earthing system employs steel conductors as electrode which are copper claded and utilize graphitic compounds and non corrosive salts as “ Ground Enhancing Material” which do not lead to corrosion. Such earth pits also do not require the usual watering schedules to maintain the earth resistance within limits. Maintenance free earths are to be constructed as per **RDSO’s specification no. RDSO/ PE/ SPEC/ 0109-2008 (REV‘0’)**.

Where the earth pits are not easily accessible for schedule maintenance, maintenance free earth pits shall be provided. In areas where clusters of earth pits are required to keep the earth resistance low, provision of maintenance free earth pits should be made during initial installation.

4.10.1 Earth Resistance

The earth resistance value at earth bus bar should be less than 0.5 ohms for major electrical equipment & installation.

4.10.2 Applications

This earthing system may be used in following locations.

- Sub stations & switching stations
- Remote Terminal Units
- Transformer & Generator neutral earths
- Lightning arrester earths
- Equipment earths including panels

Chapter 5

GENERAL

5.1 ELECTRICAL ENERGY BASICS

Electric current is divided into two types viz. Directional Current (DC) which is non-varying unidirectional electric current (Example: Current produced by batteries) and Alternating Current (AC), which reverses in regularly recurring of time and which has alternately positive and negative values occurring a specified number of times per second. For example: Household electricity produced by generators, Electricity supplied by utilities.

- **Ampere (A)**

Current is the rate of flow of charge. The ampere is the basic unit of electric current.

- **Voltage (V)**

The volt is the International System of Unit (SI) measure of electric potential or electromotive force. A potential of one volt appears across a resistance of one ohm when a current of one ampere flows through that resistance.

- **Resistance**

Resistance = Voltage/ Current
The unit of resistance is ohm (Ω)

- **Frequency**

The supply frequency tells us the cycles at which alternating current changes. The unit of frequency is hertz (Hz: cycles per second).

- **Kilovolt Ampere (kVA)**

It is the product of kilovolts and amperes. This measures the electrical load on a circuit or system. It is also called the apparent power.

For a single phase electrical circuit, Apparent power (kVA) = $\frac{\text{Voltage} \times \text{Amperes}}{1000}$

For a three phase electrical circuit, Apparent power (kVA) = $\sqrt{3} \times \frac{\text{Voltage} \times \text{Amperes}}{1000}$

- **KVAr (Reactive Power)**

KVAr is the reactive power. Reactive power is the portion of apparent power that does not work. This type of power must be supplied to all types of magnetic equipment, such as motors, transformers etc. larger the magnetizing requirement, larger the kVAr.

- **Kilowatt (kW) (Active Power)**

kW is the active power or the work-producing part of apparent power.

For single phase, Power (kW)

$$= \frac{\text{Voltage} \times \text{Ampere} \times \text{Power factor}}{1000}$$

For three phase, Power (kW)

$$= \sqrt{3} \times \frac{\text{Voltage} \times \text{Amperes} \times \text{Power factor}}{1000}$$

- **Power Factor**

Power Factor (PF) is the ratio between the active power (kW) and apparent power (kVA).

$$\begin{aligned} \text{Power Factor (Cos}\Phi \text{)} &= \frac{\text{Active Power (kW)}}{\text{Apparent Power (kVA)}} \\ &= \frac{\text{kW}}{\sqrt{(\text{kW})^2 + (\text{kVAr})^2}} \\ &= 1.0 \text{ (when kVAr} = 0\text{)} \end{aligned}$$

When current lags voltage like in inductive loads, it is called lagging power factor and when current leads voltage like in capacitive loads, it is called leading power factor.

Lower the power factor; electrical network is loaded with more current. It would be advisable to have highest power factor (close to 1) so that network carries only active power which does real work.

- **Kilowatt-hour (kWh)**

Kilowatt-hour is the energy consumed by 1000 Watts load in one hour. If 1kW (1000 watts) of an electrical equipment is operated for 1 hour, it would consume 1 kWh of energy (1 unit of electricity).

- **Electricity Tariff**

Calculation of electric bill for a H.T. consumer

Electrical utility or power supplying companies charge industrial customers not only based on the amount of energy used (kWh) but also on the peak demand (kVA) for each month.

- **Contract Demand**

Contract demand is the amount of electric power that a customer demands from utility in a specified interval. Unit used is kVA. It is the amount of electric power that the consumer agreed upon with the utility. This would mean that utility has to plan for the specified capacity.

- **Maximum Demand**

Maximum demand is the highest average kVA recorded during any one-demand interval within the month. The demand interval is normally 30 minutes, but may vary from utility to utility from 15 minutes to 60 minutes. The demand is measured using a tri-vector meter/ digital energy meter.

- **PF Measurement**

A power analyzer can measure PF directly, or alternately kWh, kVAh or kVARh readings are recorded from the billing meter installed at the incoming point of supply. It would be advisable to have higher power factor (close to 1). An incentive is given for higher power factor and a penalty is imposed for lower power factor by utility in billing of user.

5.2 POWER FACTOR

The majority of ac electrical machines and equipment draw from the supply an apparent power (kVA) which exceeds the required useful power (kW). This is due to the reactive power (kVAR) necessary for alternating magnetic field.

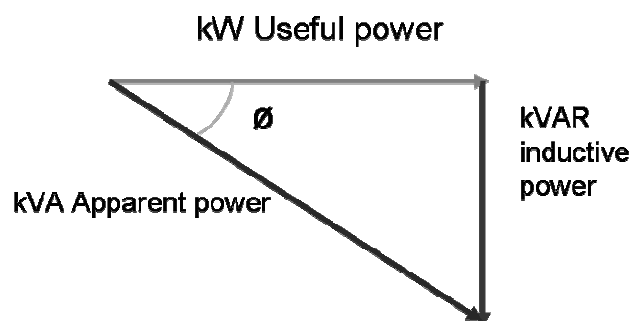
The ratio of useful power (kW) to apparent power (kVA) is termed the power factor of the load. The reactive power is indispensable and constitutes an additional demand on the system.

The power factor indicates the portion of the current in the system performing useful work. A power factor of unity (100 percent) denotes 100 percent utilisation of the total current for useful work whereas a power factor of 0.70 shows that only 70 percent of the current is performing useful work.

5.2.1 Principal Causes of Low Power Factor

The following electrical equipment and apparatus have a lower factor:

- Induction motors of all types particularly when they are under loaded.
- Power transformers and voltage regulators
- Arc welders
- Induction furnaces and heating coils.
- Choke coils and magnetic systems.
- Fluorescent and discharge lamps, neon signs etc.
- The principal cause of a low power factor is due to the reactive power flowing in the circuit. The reactive power depends on the inductance and capacitance of the apparatus.



5.2.2 Effect of Power Factor to Consumer

The disadvantages of low power factor are as follows:

- Overloading of cables and transformers
- Decreased line voltage at point of application.
- Inefficient operation of plant.

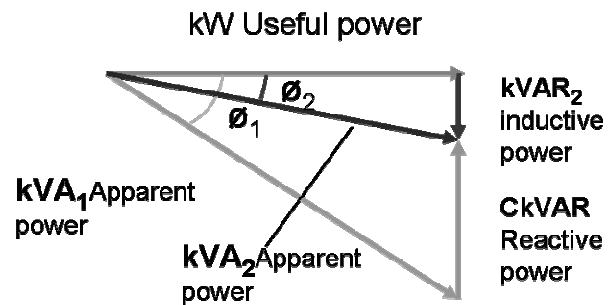
The advantages of high power factor are as follows:

- Reduction in the current.
- Reduction in power cost.
- Reduced losses in the transformers and cables.
- Lower loading of transformers, switchgears, cables, etc.
- Increased capability of the power system
- Improvement in voltage in voltage conditions and apparatus performance, and
- Reduction in voltage dips caused by welding and similar equipment.

5.2.3 Power Factor Calculation

- In initial condition
 - $kVAR_1 = kW \times \tan \phi_1$
 - In improved condition
 - $kVAR_2 = kW \times \tan \phi_2$
 - Now,
- $$CkVAR = kVAR_1 - kVAR_2$$

$$\underline{CkVAR = kW (\tan \phi_1 - \tan \phi_2)}$$



5.3 ECONOMICS OF POWER FACTOR IMPROVEMENT

Static capacitors, also called static condensers, when installed at or near the point of consumption, provide necessary capacitive reactive power relieve distribution system before the point of its installation from carrying the inductive reactive power to that extent.

The use of the static capacitors is an economical way of improving power factor on account of their comparatively low cost, ease of installation. less maintenance, low losses and the advantage of extension by addition of requisite units to meet the load growth. Installation of capacitors also improves the voltage regulation and reduces amperes loading and energy losses in the supply apparatus and lines.

The minimum permissible power factor prescribed in the conditions of supply of Electricity Boards or Licensees and the reduction in charges offered in supply tariffs for further improvement of power factor shall along with other considerations such as reduction of losses etc. determine the kVAR capacity of the capacitors to be installed.

5.4 USE OF CAPACITORS

The successful operation of power factor improvement depends very largely on the positioning of the capacitor on the system. Ideal conditions are achieved when the highest power factor is maintained under all load conditions.

Individual Compensation - Wherever possible the capacitor should be connected directly across the terminals of the low power factor appliance or equipment.

Group Compensation - In industries where a large number of small motors or other appliances and machines are installed and whose operation is periodical it is economical to dispense with individual installation of capacitors. A bank of capacitors may be installed to connect them to the distribution centre of main bus-bars of the group of machines.

Central Compensation - Capacitors may also be installed at a central point that is at the incoming supply or service position. In order to overcome problems of drawing leading currents on light loads, these capacitors may be operated manually or automatically as required. The automatic control is preferred as it eliminates human errors.

Operation may be arranged by means of **AUTOMATIC POWER FACTOR CORRECTER** and maintains the correct amount of kV AR in the circuit.

The method of connecting power factor capacitors to supply line and motors is given in figures.

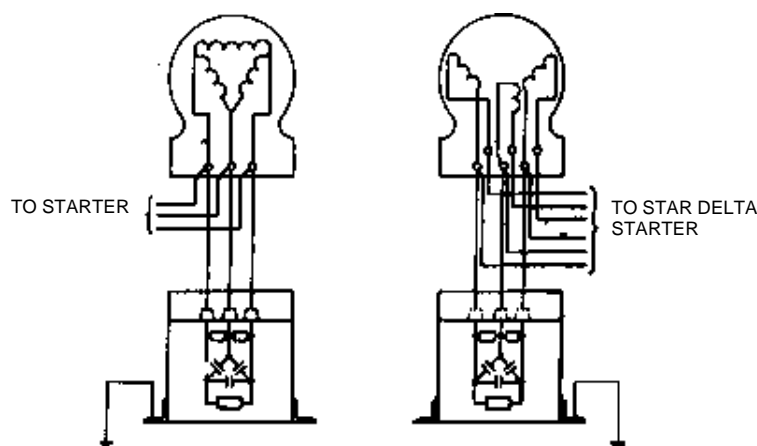


Figure Methods of connecting capacitors for improvement of power factor to motors

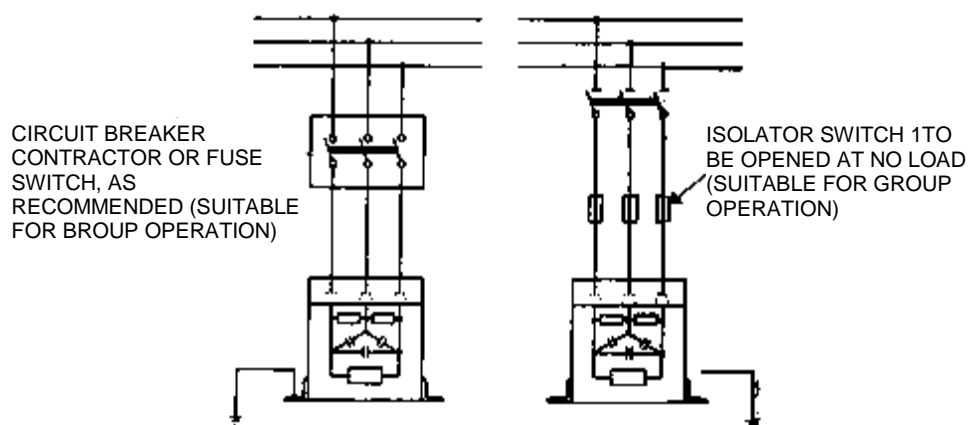


Figure Methods of connecting capacitors for improvement of power factor to supply line

5.5 WHAT IS ENERGY CONSERVATION

Energy conservation means “Reducing energy consumption by adopting energy consuming efficient measures in various sectors”. It means

- Reducing energy consumption
- Avoiding wastage of energy.

5.6 PERMIT TO WORK

- To be issued by an authorized person.(An authorized person means a person authorized under Rule-3 of Indian Electricity Rules,1956.)
- To be signed by an authorized person
- The point at which it is safe to work.
- Time period.
- Step taken for safety like earthing etc.
- After completion of the work permit to work to be cancelled by those doing the work.

5.7 COMMON SAFETY PRECAUTION

Whenever in a substation, any maintenance work is undertaken following safety precautions should be observed.

- Access to live parts should be prevented by using enclosures.
- Verify that the equipment to be maintained is isolated from all sources.
- All auxiliary supplies should be isolated, springs of spring mechanism to be discharged and air of the pneumatic mechanism to be exhausted.
- Equipment, which is isolated from supply for maintenance, should be earthed before touching it.
- Whenever safety interlocks are provided, steps should be taken to effectively use them.

Apart from precautions, factors like clarity of layout, accessibility of installation, live line indicators and segregation can contribute substantially to the safety during operation and maintenance work.

The following minimum clearances shall be maintained for bare conductors or live parts of any apparatus in outdoor substations, excluding overhead lines of HV/ EHV installations.

Voltage Class (Not exceeding)	Ground clearance (Meters)	Sectional/safety/ working clearances (Meters)
11 KV	2.75	2.6
33 KV	3.7	2.8
66 KV	4.0	3.0
132 KV	4.6	3.5
220KV	5.5	4.3
400KV	8.0	6.5

5.8 ILLUMINATION SYSTEM IN SUB-STATION

5.8.1 Yard Illumination

Proper illumination is required for operation and attending fault repair in a substation; in case of an outdoor substation yard should be uniformly illuminated. Required illumination level of yard is 20 lux. So while designing a sub-station design of lighting arrangement must be kept in mind. Height of luminaire and type of lamp should be combined properly.

5.8.2 Emergency Lighting system in sub-station

Emergency lighting is needed in case of failure of AC supply. In indoor location such as switchgear room etc. provision of suitable lamps connected to solar voltaic cell system or battery should be made at suitable locations which are brought in service in case of AC supply failure. These are normally wired through automatic changeover contactors at the DC distribution boards.

5.9 FIRE FIGHTING ARRANGEMENT

For safety of a sub-station and human being fire fighting arrangements are maintained as per I.E. Rule 1956. A sub-station must have buckets filled with fine dry sand and ready for immediate use for extinguishing fires, in addition to fire extinguishers suitable for dealing with electric fires, shall be conspicuously marked and kept in all sub-stations. The fire extinguishers shall be tested for satisfactory operation at least once a year and record of such tests shall be maintained.

Suitable fire extinguisher, properly maintained, and staff trained with using them; also precaution should be made regarding oil in equipments and locations. Training record shall be maintained.

Fireman's axe is also one of important equipment to be kept in sub-station required for disconnection of live wire or line in case of emergency. Though the axes are to be tested to 20000 volts their use should be limited to 1000 to 10000 volts with precautions. The fact that the handle is covered with the insulating material does not guarantee the user safe working against electric shock.



Uses:- To cut live electric wires, after observing all cautions, to twist off padlocks, to cut through wooden obstruction in an emergency, to break glass window panes.

5.10 LIST OF SUPPORTING AND OTHER AUXILIARY ITEMS AT SUB-STATION

- First Aid box- The first aid box shall be provided at suitable location.
- Safety belt
- Fire extinguishers
- Fire buckets
- Hand gloves
- Gum boots
- Stretcher
- Earth discharge rod
- Rain coat
- Torch
- Helmet
- Tool kit
- Infrared thermal imaging camera
- Shock treatment chart
- Properly painted notice cum display boards, such as “MEN ON WORK”, “FUALTY LINE” etc..

5.11 INSTRUCTIONS FOR RESTORATION OF PERSON SUFFERING FROM ELECTRIC SHOCK

Under rule 44 (1) of the Indian Electricity rules, 1956, instructions for restoration of persons suffering from electric shock, in English or Hindi and the local language shall be affixed in a conspicuous place in every sub- station for the restoration of persons suffering from electric shock. Every employee is required to make himself familiar with the instructions so that they can follow rapidly.

ANNEXURE - A**TESTING OF TRANSFORMER OIL**

In order to improve the performance and to prolong the life of the transformers, EHV grade oil is used as per the requirement laid down by RDSO. Application and interpretation of tests on transformer oil in service is given below.

Application and Interpretation of Tests on Transformer Oil in Service

Sr.	Tests	Value as per IS: 1866		
		Permissible limits	To be re-conditioned	To be replaced
1.	Electric strength (Breakdown voltage) Below 72.5 kV	Min. 30 kV	Less than the value specified	If minimum value is not attained after reconditioning.
2.	Specific resistance (Resistivity) Ohm/cm at 27°C	Above 10×10^{12}	Between 1×10^{12} to 10×10^{12}	Below 1×10^{12}
3.	Water content Below 145 kV	Max. 35 ppm	Greater than the value specified.	-
4.	Dielectric dissipation factor, Tan delta at 90°C.	0.01 or less	Above 0.01 to 0.1	Above 0.1
5.	Neutralization Value mg KOH/g of oil.	0.5 or Less	Above 0.5	Above 1.0
6.	Interfacial tension N/m at 27°C.	0.02 or more	0.015 and above but below 0.02	Below 0.015
7.	Flash point in °C	140 or more	125 and above but below 140	Below 125
8.	Sludge	Non-detectable	Sediment	Perceptible sludge

Important Characteristics of New Oil when Tested at the Manufacturer's Works (Ref: IS 335)

S. No	Characteristics	Test Method (Ref. to IS: or Appendix)	Requirements
1.	Appearance	A representative sample in 100 mm thick layer	The oil is clear and transparent free from suspended matter or sediments.
2.	Electric strength (break down voltage) a. New unfiltered oil. b. After filtration.	IS: 6792-1972	a. Min. 30 kV (rms) b. If the above value is not attained, the oil shall be filtered, 60 kV(rms), RDSO's requirement.
3.	Resistivity at a. 90°C b. 27°C	IS: 6103-1971	Min. 35×10^{12} Ohm-cm 1500×10^{12} Ohm-cm
4.	Dielectric dissipation factor (tan delta) at 90°C	IS: 6262-1971	Max. 0.002

S. No	Characteristics	Test Method (Ref. to IS: or Appendix)	Requirements
5.	Water content	Appendix E of IS: 335-1983	Max. 50 ppm
6.	Interfacial tension at 27°C	IS: 6104-1971	Min. 0.04 N/m
7.	Flash point	IS : 1448	Min. 140°C
8.	Dissolved gas content		4 – 8%
9.	Neutralization value a. Total acidity b. Inorganic acidity/alkalinity	IS: 1448 - do -	a. Max. 0.03 mg KOH/g b. Nil

Purification of Transformer Oil

The object of oil purification is to remove all contaminants such as water, carbon deposits, dirt, sludge, dissolved moisture and gases. The most important quality to be preserved is the di-electric strength, which is affected by presence of moisture.

The insulating material used in the winding are hygroscopic in nature and therefore moisture is absorbed through defective breathers, gasket and addition of untreated make up oil. It is essential to remove these impurities in purifying the oil when the di-electric strength goes below the permissible limits.

For purifying the transformer oil, machine conforming to RDSO's specification no.ETI/PSI/103 may be used.

Oil Sampling

General precautions

- Use always clean, dry and amber glass bottles as per IS: 6855-1973
- Take oil sample preferably in dry weather and avoid any external contamination.
- Oil sample shall be at least as warm as the ambient air.

Sampling procedure

- First drain at least one liter oil to eliminate any contaminations which is accumulated in the drain cock.
- Rinse the bottles with the oil being sampled.
- After taking the sample, ensure that the cock is correctly closed.
- Check that the label marking are correct and complete.
- Store samples in a dark place.
- Ensure that the sampling is done by an experienced person.
- Ensure that each of sampling bottle is filled up to 95 to 98 percent of its capacity.

ANNEXURE -B**CONDITION MONITORING OF TRANSFORMER BY DISSOLVED GAS ANALYSIS****➤ INTRODUCTION**

In order to detect incipient faults in the transformer and to arrest deterioration/ damage to the transformer insulation, gases dissolved in the transformer oil are detected, analysed and preventive measures adopted.

Gas Chromatography method is used for detection of the dissolved gases and identification of incipient faults. The most significant gases generated by decomposition of oil and deterioration of paper insulation on the conductor are hydrogen, methane, ethane, ethylene and acetylene. The quantities of these gases dissolved in transformer oil vary depending upon the type and severity of the fault conditions.

➤ SENSITIVITY LIMITS

Gas Chromatography apparatus should be able to detect the following minimum concentration of dissolved gases:

Hydrogen	:	5 ppm
Hydrocarbon	:	1 ppm
Carbon oxides	:	25 ppm

➤ ESTABLISHMENT OF REFERENCE VALUES/ BENCH MARKS

To establish a reference value/ bench mark, gas as generated from initial sample of oil from each healthy transformer should be collected. Results of the analysis are taken as a reference value/ benchmark. Results of later periodic analysis are compared with the benchmark for each transformer.

➤ ESTABLISHMENT OF NORMS

The contents of various dissolved gases in the transformer oil vary with design and operating conditions. It is desirable that the values of concentration of gases of healthy transformers of different age groups are to be gathered by the Railways concerned to evolve suitable norms. However, as a starting point, the permissible concentrations of dissolved gases in the oil of a healthy transformer are given below as guidelines:

Gas	Less than 4 years in service (ppm)	4-10 years in service (ppm)	More than 10 years in service (ppm)
Hydrogen (H ₂)	100/150	200/300	200/300
Methane (CH ₄)	50/70	100/150	200/300
Acetylene (C ₂ H ₂)	20/30	30/50	100/150
Ethylene (C ₂ H ₄)	100/150	150/200	200/400
Ethane (C ₂ H ₆)	30/50	100/150	800/1000
Carbon dioxide (CO ₂)	3000/3500	4000/5000	9000/12000

➤ **DIAGNOSIS OF FAULT**

Basic Diagnosis of DGA is based upon the quantities of gases generated. Types of gases in excess of norms produced by oil decomposition/ cellulosic material depend upon the hot spot temperature produced by faults.

Characteristics of gases associated with various faults are as under:

Methane (CH ₄)	Low temperature hot spot
Ethane (C ₂ H ₆)	High temperature hot spot
Ethylene (C ₂ H ₄)	Strong over heating
Acetylene (C ₂ H ₂)	Arcing
Hydrogen (H ₂)	Partial discharge
Carbon dioxide (CO ₂)	Thermal decomposition of paper insulation
Carbon monoxide (CO)	

➤ **WORD OF CAUTION**

To start with the diagnosis, it is necessary to be satisfied that measured gas concentrations are significant and high enough to warrant diagnosis, because some amount of gases will always be there due to normal operating conditions without any fault but it can be sufficient to be misleading. The reasons for the situation are:

- Gases formed during the refining processes and not completely removed by oil degassing.
- Gases formed during drying and impregnating the transformer in sheds/ workshops.
- Gases formed in the event of previous faults and not completely removed from the oil impregnated insulation before being refilled with degassed oil.
- Gases formed during repairs by brazing, welding, etc.

➤ **PROCEDURE FOR FAULT DIAGNOSIS**

- Obtain the results of concentration of various gases in terms of microlitre (ppm).
- Compare the concentrations with sensitivity limits. These should be at least ten times sensitivity.
- If it exceeds sensitivity limits, compare with benchmarks.
- If it exceeds benchmarks, compare concentrations with norms depending upon age and design of transformer.
- If one or more gases are above norms, compare with the last sample results; if increase is sufficient, obtain a check sample.
- If the check sample confirms the results, calculate the rate of increase of gas. If rate of increase is more than 10% per month, it is considered rapid and warrants immediate further investigations including lifting of core and internal inspection.
- If the gas production rate is medium, i.e., less than 10% per month, sampling frequency to be increased from quarterly to monthly.
- Take a planned shut down for further investigation.

ANNEXURE– C**INFRARED THERMAL IMAGING CAMERA****CHECKING OF ELECTRICAL LOOSE CONNECTIONS AND HIDDEN FAULTS**

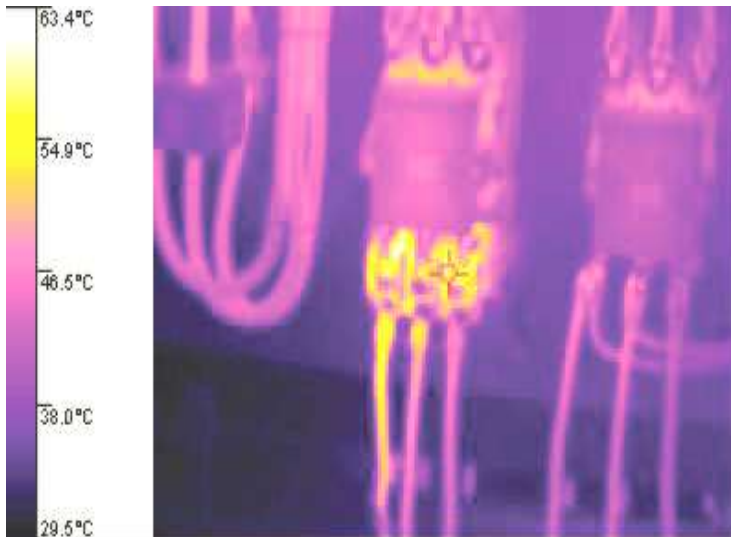
Failure of electrical & mechanical devices is because of component failure or electrical loose connections. Failure such as overhead line problem, problem in electric connections, overheating, hidden faults and insulation defect etc results in thermal heating. Infrared thermal imaging camera can detect electrical hot spots on faulty equipment and hidden faults, when conducting routine survey of electrical system.



For detailed technical specifications please refer **RDSO specification No.TI/ SPC/ OHE/ TIPS/ 1030 (6/ 2005) Rev. 1**

Advantages

1. It helps to find out electrical hot spots and faulty equipments in incipient conditions.
2. It is an ideal means for professionals looking for safety and reliability when conducting routine surveys of electrical systems, switchgear and electrical components.
3. It is a light weight, comfortable and sensitive test instrument with touch screen, text features.



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OUR OBJECTIVE

To upgrade maintenance technologies and methodologies and achieve improvement in productivity, performance of all Railway assets and manpower which inter-alia would cover reliability, availability, utilisation and efficiency.

If you have any suggestions and any specific Comments please write to us.

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